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A

TREATISE ON VENTILATION:

COMPRISING SEVEN LECTURES DELIVERED BEFORE THE FRANKLIN INSTITUTE, PHILADELPHIA, 1866–68.

SHOWING THE GREAT WANT OF IMPROVED METHODS OF VENTILATION IN OUR BUILDINGS;

GIVING THE CHEMICAL AND PHYSIOLOGICAL PROCESS OF RESPIRATION;

COMPARING THE EFFECTS OF THE VARIOUS METHODS OF HEATING AND LIGHTING UPON THE VENTILATION.

ILLUSTRATED BY MANY PLANS OF ALL CLASSES OF PUBLIC AND PRIVATE BUILDINGS SHOWING THEIR PRESENT DEFECTS, AND PROPOSING THE BEST MEANS (IN THE AUTHOR'S JUDGMENT) OF IMPROVING THEM.

BY LEWIS W. LEEDS.

"Man's own breath is his greatest enemy."

SECOND EDITION.

NEW YORK:
JOHN WILEY & SONS, PUBLISHERS,
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1876.

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PREFACE TO FIRST COURSE OF LECTURES.

THESE Lectures were not originally written with any view to their publication; but as they were afterwards requested for publication in the Journal of the Franklin Institute, and there attracted very favorable notice, I believed the rapidly increasing interest in the subject of ventilation would enable the publishers to sell a sufficient number to pay the expense of their publication; and, if so, that this very spirit of inquiry which would lead to the perusal of even so small a work, might be one step forward towards that much-needed more general education on this important subject.

It was not my desire to give an elaborate treatise on the subject of ventilation. I believed a few general principles, illustrated in a familiar way, would be much more likely to be read; and, I hoped, would act as seed-grain in commencing the growth of an inquiry which, when once started in the right direction, would soon discover the condition of the air we breathe to be of so much importance that the investigation would be eagerly pursued.

L. W. L.

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PREFACE TO SECOND EDITION.

So great has been the change, that, in revising these Lectures and adding the Second Course for publication, it seems scarcely possible that two or three short years only could have passed since the general indifference and apathy, as therein expressed, should have existed.

But I remember well it seemed like a pall, a dead weight upon me, that I could not arouse or shake off. To be sure, that was in Philadelphia, the slowest place for adopting new ideas in the country. But it is very gratifying, and pays for many long years of labor and discouragement, to see so radical a change in public sentiment, and so healthy a growth in the true understanding and appreciation of correct principles of Ventilation, as is every day developing itself.

It is a little curious as well as interesting to watch the current of change in public opinion. Less than ten years ago probably ninety-nine out of every hundred thought the *only* place for the escape of the foul air must be from the upper part of a room. But, owing to the general adoption of that national curse—hot air—it was found that in winter both the heat and fresh air, being one, escaped through such openings and were wasted. Now, nine out of ten persons think the only place for such escape should be from the bottom, without any reference to the manner of heating.

In a short time the views of most persons will be changed, no doubt, on this subject, as they have now commenced learning that all warmed air is debilitating;—that we should breathe fresh, cool air, and be warmed by some other means, say by radiation from open fires, or by exposed pipes heated by circulating water or steam.

The idea of warming the floors and exterior walls seems to strike every one as judicious, and is now being adopted and inserted in the plans of most of our new buildings.

Then of course when we are receiving warmth from the solid objects of a room, instead of those objects absorbing the animal heat from our bodies,

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the conditions are entirely changed; the fresh air may then enter cooler, and will naturally flow under the fouler air that has been longer in the room, and will rise towards the ceiling in unison with that warmer and fouler current that is always rising around and above the body. Under such conditions it is best to allow a liberal escape from the ceiling.

It has been my endeavor to illustrate, as clearly as possible, this intimate connection between the ventilation and warming, and to give a sufficient number of examples to assist the thoughtful student to start on the right track; being careful at the same time not to assume that we have already arrived at perfection in this particular, but remembering we have but just commenced the study of this important subject.

I have not been particular, in selecting plans for illustration, to take such only as have been fully executed; on the contrary, I have used some which I think will not be executed at all. Because with the present very limited general knowledge upon the subject of ventilation, the opinions of different individuals are so various and unreliable as to more frequently lead astray than towards the exact truth, and certificates or opinions from interested parties, either in favor of or in condemnation of the ventilation of any particular building, are of little value.

Very frequently we find buildings in which the natural ventilation by halls or large flues is excellent; yet the same will be condemned in the strongest terms as entirely deficient in ventilation, simply because there is not the show of registers or little twirly-bobs that many think so necessary to produce good ventilation.

On the contrary, nearly every architect has some good story to tell you of how he has succeeded in securing the most excellent results (upon the minds of some Church committee or owner of house) by putting large ventilating registers in what he knew to be the solid wall or air-tight space over the ceiling.

Therefore I have made but little attempt to catch public notice by claiming some wonderful new invention, and getting a long list of certificates from prominent men as to its great success; but I have endeavored more particularly to call attention to general principles by which each individual must be guided in his study of the important but complicated problem, of how he shall, at all times and under all circumstances, supply himself with the necessary warmth and pure air for the most perfect physical existence and development, relying more upon the aggregate result of a general agitation of the subject, than upon individual opinions, for my justification and encouragement.

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FIRST COURSE,

DELIVERED BEFORE THE FRANKLIN INSTITUTE,

DURING THE WINTER OF 1866-67.

UNIVERSITY OF CALIFORNIA.

LECTURE I.

PHILADELPHIA is one of the healthiest cities in the United States, and, in proportion to the number of its inhabitants, few more healthy cities exist in the world.

This is not owing especially to its more salubrious situation, but should be attributed, in a great measure, to the accidental superiority of the ventilation of a large proportion of its dwelling-houses.

Notwithstanding this comparative excellence, the theory of ventilation is not so thoroughly understood, nor is the practice so perfect, even in this city, that no advantage can be gained by further knowledge upon the subject.

Far from it. From the very best information we can command, and with the most accurate statistics at our disposal, we are forced to the conclusion that about forty per cent. of all the deaths that are constantly occurring are due to the influence of foul air.

The Registrar of Records of New York gives nearly half the deaths in that city as resulting from this cause.

The deaths in this city for 1865, according to the report of the Board of Health, were seventeen thousand one hundred and sixty-nine; the average age of those who died was between twenty-three and twenty-four years. It ought to have been twice that, as shown by some districts in the city and also in the country, where the houses are so arranged that they frequently have good ventilation.

Taking the deaths caused by foul air at a very low estimate, say forty per cent. of the whole, (the per centage from that cause is not so great as in New York,) we have six thousand eight hundred and sixty-eight deaths in this city, caused alone by impure air, in one year.

It is estimated by physicians that there are from twenty-five to thirty days of sickness to every death occurring; there would therefore be something like two hundred thousand days of sickness annually as an effect of foul air.

We all know how very expensive sickness is, but few persons realize

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the enormous aggregate expense of unnecessary sickness in a city like Philadelphia.*

This subject has awakened much interest in Europe of late years, and has led to the expenditure of immense sums of money, for the purpose of improving the sanitary condition of its cities.

Dr. Hutchinson estimated the loss to the city of London, growing out of preventable deaths and sickness, at twenty millions of dollars annually, and Mr. Mansfield estimates the loss from this cause to the United Kingdom at two hundred and fifty millions of dollars.

In the single State of Massachusetts, an estimate exhibits an annual loss of over sixty millions of dollars by the premature death of persons over fifteen years of age.

It is estimated that a few only of the principal items of expense incurred by preventable sickness in the city of New York amount to over five millions of dollars annually.

And if it is thought that Philadelphia is exempt from such enormous unnecessary expense, just glance at the report of the Board of Health for last year, and see how the deaths from disease of the lungs largely exceed those from any other disease.

Consumption is almost entirely the result of breathing impure air,—it is as preventable by the exclusive use of pure air as *maniaa potu*or drunkenness is by the exclusive use of pure water. And see, too, what slaughter among the innocents—over twenty-five per cent. of the whole deaths were under one year of age.

The infantile mortality is by many considered the most delicate sanitary test. But why does such an intelligent community as this so neglect its own interest?

They have listened to and satisfied the first imperative demands of nature—shelter from the elements and warmth,—and in doing this they have not brought into use that much higher order of intellect which can alone teach them how to supply, in connection with an agreeable warmth, an abundance of pure air in their otherwise air-tight houses.

I have been much interested in examining a large collection of tables of the analysis of air, which accompany a report to Congress, on "Warming and Ventilating the Capitol," prepared by Thomas U. Walter, Professor Henry and Dr. Wetherill. These tables were made by men of various nations, giving the results of their analysis of air

* I mean merely pecuniarily—in dollars and cents;—the cost in physical pain and mental anxiety, of course, cannot be computed in dollars and cents.

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taken from all manner of places, from great elevations on the mountains and in balloons, from the valleys, from the centre of the ocean, and from the middle of the continent, in cities and in the country, in winter and in summer, at night and in the day, and also the comparative analysis of the air *out of doors and in houses.* Believing that these would be of much interest and assistance to us in the investigation of the subject under consideration, I have had copies made of some of the most interesting.

These give the per centage of carbonic acid in the air as the test of the amount of impurities in it.

This is not an infallible test by any means—there are various other causes of deterioration. There is the exhaustion of the oxygen constantly occurring to support combustion and animal life; there are various other deleterious products of combustion and respiration besides carbonic acid. But, as carbonic acid is always found in certain known proportions in pure air, and is always formed in certain known quantities by respiration or combustion, it is considered by many to give a very fair indication of the condition of the atmosphere with reference to its influence on animal life or combustion.

I think one of the most valuable lessons to be learned by the study of these tables is the uniform purity of the external atmosphere all over the world, even in large cities.

This is strikingly illustrated in the case of the analysis of the air in the city of Manchester.

We have nothing in this country like that city, where two millions of tons of coal are burned annually, the smoke from which fills the air and stretches like a black cloud far into the country.

Thus, added to the five hundred tons of carbonic acid thrown from the lungs of its animal life every day, are many times that amount, (some two thousand tons,) daily, pouring out from its forest of factory chimneys.

To this city were the labors of the "Health of Towns Commission" first directed, to see if they could not find in the air of its streets that mysterious influence that has caused such alarm throughout the civilized world, as the thoughtful and intelligent sanitarian sees one-half of all his fellow-citizens hurried to untimely graves.

They were disappointed, and well might Dr. Smith exclaim, after the most thorough and careful investigations, "How insignificant are the works of art in contaminating that vast ocean of air that is constantly sweeping over the surface of the earth!" But do not be dis-

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couraged: more recent investigations have discovered the whereabouts of this pestilential breath.

I have placed the table of Dr. Angus Smith's analysis of the air of Manchester at the head of the list, and have copied it complete, because it is the only table that I have examined of the analysis of the air of towns in Europe or North America, in which there occurs an amount of carbonic acid exceeding ten parts in ten thousand.

Here we see three such cases in the twenty-eight experiments, one ten, one twelve and one fifteen.

The average of the whole is also greater than in any other similar tables, being about seven and a half parts in ten thousand. This is certainly quite a perceptible contamination, pure air containing four or four and a half parts in ten thousand. Yet considerable as this appears in this view, the additional amount of carbonic acid is only the proportion that would be added to the air, if unchanged, of a room fifteen feet square and ten feet high, by a father, mother and three children, with a gas-light, in seven minutes.

And this, probably, is the highest average contamination that is produced by artificial means upon the air of any city in the world.

There are, of course, great natural causes which affect the air of whole countries, such as the decomposition of great masses of vegetable matter similar to that occurring on the low flat lands along rivers, especially where they overflow their banks, like the Ohio and Mississippi. The best system of ventilation, as applicable to this kind of foul air, is to keep as far out of its reach as possible.

The other tables giving the analysis of the air of London, Paris, Madrid, Geneva, Bolton, England, at different elevations on the mountains, on the Atlantic Ocean, Washington City and various other places, are interesting only because they show so great a uniformity in the carbonic acid, seldom exceeding six parts to the ten thousand, and seldom under four.

But now let us look upon the other side of the room. Here we have tables giving the "carbonic acid in houses." Here we will find very different results. But the first is a green-house; in that there is no trace of carbonic acid in the evening and scarcely a trace in the morning. Plants, you know, absorb the carbonic acid, and give off oxygen, while animals absorb the oxygen and give off carbonic acid, thus keeping up the equilibrium in nature, as is so beautifully shown in the aquarium. Plants are generally supposed to give off carbonic acid at night, but it must be in very small quantities.

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I consider them very conducive to health in a living-room, morally and physically.

But this want of carbonic acid does not last long.

The next is M. Dumas' lecture-room. At commencement of lecture 42·5, and at close of lecture 67 parts in ten thousand.

Now, I think we are on the right track for discovering that mysterious poison that has carried so many of our friends to their graves, even in the very prime of life.

Here we have dormitories, 52; do., 37; asylum, 17; school-room, 30; do., 56; Chamber of Deputies, 16; Opera Comique, parterre, 15; do., ceiling, 28; stable, 7; do., 14; hospital, Madrid, 30; do., do., 43; air of bed-room on rising in the morning, 48; the same after being ventilated two hours, 16; railroad car, 34; workshop, Munich, 19; full room, do., 22; lecture-room, 32; beer-saloon, 49; and worst of all is a well-filled school-room, 72 parts of carbonic acid in 10,000.

That, I think, is enough. Here we have the solution of the whole mystery.

It is not in the external atmosphere that we must look for the greatest impurities, but it is in our own houses that the blighting, withering curse of foul air is to be found. We are thus led to the conclusion that *our own breath is our greatest enemy.*

The "Health of Towns Commission," in their investigations, after examining various trades, where the employees were confined mostly in houses, and having left the scavengers to the last, expecting to find a rich harvest of mortality among them, were much surprised to find them more healthy than many very clean occupations, but which were conducted in houses instead of in the open air. I have not the statistics before me, but I should not be surprised to learn that that singular race of beings that live in the sewers of Paris were as healthy, if not even more so, than the operatives of some of those exquisitely beautiful, clean, air-tight factories of New England.

There was quite an account made a few years ago of the wonderful cures of consumption that had been performed by the patient being removed to the stable where he could be in close proximity to the cow, and I have no doubt many consumptive patients would find great benefit by such a course of treatment, not that there is any virtue in the smell of the cow, but that the air of the cow-stable would be nearer pure than that of their own chamber.

Many go or send their families to the country in summer to get fresh air. Some go to the sea-side, others to the mountains; but there en-

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sues a greater change in a few minutes in a close bed-room by being occupied by a family than there is difference between the external air of any city and that of the country.

The reason why cities are so much more unhealthy than the country, is not because the air in the street is so much more impure, but because the houses are so built together that this vast ocean of air cannot get at and through them to purify them as it does in the houses in the country, and the reason why Philadelphia is so much more healthy than its neighbor, New York, is because the houses here are built more like those of the country, so that the air can sweep all around them, and sometimes through them.

I therefore believe, that a family living in the filthiest street in our city, if they were careful to have a constant current of air from that street, filthy as it was, passing through the house at all times, night and day, would be more healthy, other things being equal, than a family spending their winters in the finest house, if kept air-tight, in the healthiest location in the city, and their summer in the country, especially if they were always careful to exclude the *night air* from their bed-rooms.

I say "night air;"—there is, unfortunately, an unnecessary prejudice against what is termed night air, which means, I suppose, fresh external air from the dark.

To show that this is not a new idea, I will read a few lines from the writings of a very accurate reasoner and an eminently practical mechanic and philosopher, one whom I consider even now one of the very best authorities upon the subject of heating and ventilation. I mean the illustrious man after whom this Institute was named, Benjamin Franklin.

In his letter to Dr. Ingenhaus, physician to the Emperor, at Vienna, he says: * * * * "for some are as much afraid of fresh air as persons in the hydrophobia are of fresh water. I myself had formerly this prejudice—this *aerophobia*, as I now account it,—and dreading the supposed dangerous effects of cool air, I considered it an enemy, and closed with extreme care every crevice in the rooms I inhabited. Experience has convinced me of my error. I now look upon fresh air as a friend: I even sleep with an open window. I am persuaded that no common air from without is so unwholesome as the air within a close room that has been often breathed and not changed. Moist air, too, which I formerly thought pernicious, gives me now no apprehensions; for considering that no dampness of air applied to the outside of my

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skin can be equal to what is applied to and touches it within, my whole body being full of moisture, and finding I can lie two hours in a bath twice a week, covered with water, which certainly is much damper than any air can be, and this for years together, without catching cold, or being in any other manner disordered by it, I no longer dread mere moisture, either in air, or in sheets or shirts; and I find it of importance to the happiness of life, the being freed from vain terrors, especially of objects that we are every day exposed inevitably to meet with.

"You physicians have of late happily discovered, after a contrary opinion had prevailed some ages, that fresh and cool air does good to persons in the small-pox and other fevers. It is to be hoped, that in another century or two we may all find out that it is not bad even for people in health. And as to moist air, here I am at this present writing in a ship with above forty persons, who have had no other but moist air to breathe for six weeks past; everything we touch is damp, and nothing dries, yet we are all as healthy as we should be on the mountains of Switzerland, whose inhabitants are not more so than those of Bermuda or St. Helena, islands on whose rocks the waves are dashed into millions of particles, which fill the air with damp, but produce no diseases, the moisture being pure, unmixed with the poisonous vapors arising from putrid marshes and stagnant pools, in which many insects die and corrupt the water. These places only, in my opinion, (which, however, I submit to yours,) afford unwholesome air; and that it is not the mere water contained in damp air, but the volatile particles of corrupted animal matter mixed with that water, which renders such air pernicious to those who breathe it; and I imagine it a cause of the same kind that renders the air in close rooms, where the perspirable matter is breathed over and over again by a number of assembled people, so hurtful to health.

"After being in such a situation many people find themselves affected by that *febricula*, which the English alone call a *cold*, and, perhaps, from that name, imagine they have caught the malady by *going out* of the room, when it was, in fact, by being in it."

Now, to show that his hopes have not yet been fully realized, although one century has nearly closed since he wrote what I have just read, and this unnecessary and unfortunate prejudice against night air still prevails extensively, I will read a few lines from the highest public medical authority in this city. It is the instructions of the Board of Health for the prevention of cholera for 1866:

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ARTICLE—"VENTILATION."

"Your premises, particularly sleeping apartments and cellars, should be thoroughly ventilated. Ventilation is no less a purifier than water.

"It cleanses by oxidizing and drying. Keep your houses open and your windows hoisted during the day in good weather, and from ten o'clock until four in the afternoon, that they may have the full benefit of sunlight and free circulation of pure air. *During the remaining hours of the day, and through the night, keep the windows closed.* When the weather is cool or rainy, be sure to keep a fire in the house, in order to prevent dampness, or in sparsely settled neighborhoods, or in the suburbs of the city, have a fire in the house the entire season."

On page 9 we read: "Be careful to dress comfortably for the season, *avoid the night air* as much as possible, and when thus exposed, put on an extra garment and do not go into *the night air* when in a state of perspiration."

Thus, while recognizing the great value and importance of ventilation in a general way, they give the most definite instructions for thoroughly and most effectually preventing it, because it is at night, especially when we are asleep and *cannot move from the air, that the air ought to be moved from us.*

The frequent recommendations to avoid "night air" are simply recommendations to smother ourselves to death, because the foul, poisonous exhalations from our lungs cannot be removed from our chambers without being replaced by night air; there is no other fresh air at night but night air.

The recommendation to build a fire in the house on cool days, and in low marshy districts every day in the year, is an excellent one.

The recommendations to dress warmly and to avoid checking a perspiration suddenly, are valuable suggestions and too much attention cannot be paid to them.

But they are of equally great importance in reference to day air as to night air.

To shelter oneself from the sudden change of temperature after sundown is an animal instinct, and a very necessary one, which is strongly implanted in man and beast alike.

The harm comes from the fact of so intelligent and intellectual a body as the Board of Health of Philadelphia encouraging the accomplishment of this very desirable object, by thwarting that great universal law of our Creator, the ceaseless agitation of the air by which

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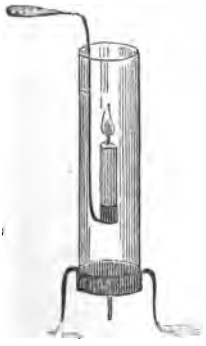
it purifies itself, (and by which perversion of nature's laws millions are already being killed unnecessarily every year,) instead of their encouraging its accomplishment in that much more healthy and rational way by adding more clothing or more fuel to the fire, and still continuing to breathe the pure air at night as well as in the day-time.

I have practised for many years sleeping with my windows open every night, summer and winter, allowing the unobstructed breeze to flow across my bed, to the great improvement of my health and strength.

There is no objection in a well ventilated room to having a fire if desired. A small room with a hot stove or open fire and the windows open, is much more wholesome than a large air-tight room freezing cold.

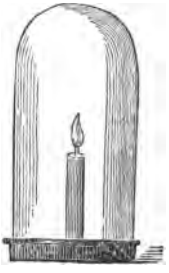
Let us illustrate this by a simple experiment. Here we have a very small tube, in which we place a lighted candle, occupying nearly the entire space—this burns brightly, you see.

Fig. 1.



Here we have another glass chamber, much handsomer and twenty times as large; we also place a similar candle in it, that burns with equal brightness, but watch them both for a few moments—see how rapidly this light in the large chamber diminishes in size.

Fig. 2.



That represents, in a beautiful manner, the diminished force of your life in an air-tight room. There it goes—entirely extinguished by foul air in so short a time, but the other continues to burn just as brightly as when first lighted. The smaller one had the window open, so to speak; we will imagine the candle in the large chamber to be a consumptive patient who thought the room so large he did not need the windows open. Remember, therefore, that no matter how small your room is, if there is a constant circulation of fresh air through it, the lamp of your life will burn brightly; but if ever so large and air-tight, your life will soon be extinguished.

Instead of averting the cholera by avoiding fresh air at night, the experience of the last summer seems to have taught us just the contrary; for whilst most physicians admit that they are still unable to explain satisfactorily, the cause or remedy for this most mysterious disease, that has within a lifetime carried its fifty millions of victims from time to eternity, they almost universally believe it is a foul air poison, and they have as yet found no surer prevention than pure air.

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One of the most striking illustrations of this, and perhaps one of the most wonderful cures of cholera on record, was that of the New York Workhouse on Blackwell's Island. It lasted only nine days, but in that brief period one hundred and twenty-three out of eight hundred inmates died. I visited the building with Dr. Hamilton, on the third day after its appearance, but the hospital then contained sixty or seventy patients, and some twenty-five or thirty had died within twenty-four hours.

Dr. Hamilton attributed the rapid propagation and fatality of the disease, after it once had gained admission, mainly to confinement and crowding. It was observed that the cholera was confined, for several days, among the women; the women had the smallest apartments, were most crowded in their cells, and with few exceptions, were employed within the building, in close contact with each other during the day. The men were employed mostly in the quarries and out of doors.

The doctor's prescription on that occasion is worth studying. It is very short and simple, however.

A slight change was made in the diet; disinfectants were used; fifteen drops of the tincture of capsicum with an ounce of whisky, as a stimulant at night, was all the medicine given to each individual. But the great means the doctor relied upon for success, was pure air all the time. They were kept out of doors from morning until night, and all the windows were kept open night and day; and although in the hot weather of summer, fire was made in the wards, to insure more perfect ventilation. In six days after the initiation of these simple hygienic measures, the epidemic entirely disappeared.

The disorders and sickness caused by the too rapid chilling of the unprotected body after sundown, have given rise, I have no doubt, to that erroneous popular prejudice so common among all classes, even those of education and ordinarily good common sense, who imagine there is some peculiar poison or source of unhealthiness in the air at night, that is not contained in the air in the day-time. It will no doubt greatly relieve the minds of these from such "vain terrors," and prove most conclusively the entire fallacy of such reasoning, to examine these tables again. In the copies I have made, I have not classified the results given by day and by night, but a careful examination in detail, fails to show any appreciable difference in the aggregate, by day or by night.

Méné's numerous experiments on the air in Paris, gave less carbonic acid at night than in the day-time.

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Lewey's analysis on the Atlantic ocean, one thousand miles from the coast, gave a decided excess in the day over that of the night. He attributes this to the action of the sunlight upon the ocean liberating the gases which it holds in solution.

In cities there is a much larger quantity given off from burning coals of factories in the day-time than at night.

It is not improbable, however, that the more rapid evaporation of moisture towards evening may carry with it the volatile particles of corrupted animal and vegetable matter to an extent slightly in excess of that which occurs in the morning, but it is believed these would not equal the greater contamination from burning coals, and the usually greater stillness of the air, producing partial stagnation, so that the air would be a little nearer pure at night than in the day-time. And how unmistakably do all these investigations prove what we ought to have known and accepted without a moment's hesitation, that the Creator, who has made such vast and such minute provisions for supplying every living creature with a constant and copious supply of fresh air, and has made it so important for their existence that they cannot live a moment without it, has made the air at night just as pure and wholesome as in the day-time.

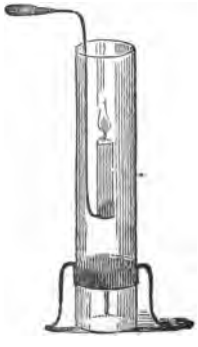
We have thus traced the scourge of foul air to our houses, and much of it to our bed-rooms. The next question is, how to get clear of it.

We want to know, however, what poisons the air, so as to know in what part of the room it is to be found.

We will try a very simple experiment, to show you what a deadly poison the breath is,—to the flame of a candle, at any rate.

Here is a simple glass tube, open at both ends—an ordinary lamp chimney—a candle burns freely as you see, and would burn so all night, if it did not burn out. I will now remove the candle, and breathe into the tube through this pipe, and now you see how suddenly the candle is extinguished as I drop it in again.

Fig. 3.



Animals are killed suddenly or after a more prolonged struggle, by the exhaled breath, according to the activity or sluggishness with which the blood circulates—a bird would be killed very soon—some partially torpid animals would live a long time. Man has great endurance—struggles long and hard; but if closely confined, will be poisoned to death in one night, as in the case of those confined in the celebrated Black Hole of Calcutta, and on board of

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vessels where they have been confined below decks in time of a storm. Others will struggle on longer, as in the case of the two thousand and twenty-six who died of consumption last year, in Philadelphia.

And now let us see in which part of the room this deadly poison of our breath is mostly found.

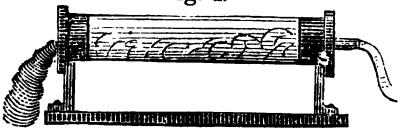
It is the popular idea, that because the body, and consequently the breath, is warmer than the ordinary temperature of a room, it rises and accumulates at the ceiling.

Upon this theory most of our buildings have been ventilated whenever any attention whatever has been given to the subject; but that theory is incorrect; consequently, all practice based thereon is also wrong.

This subject of the direction taken by the breath upon leaving the body, has been warmly discussed within a few years. It has been a very difficult matter to prove conclusively and satisfactorily, but I think we have devised some very simple experiments that will prove to you very clearly what we have stated.

I have here a simple glass tube two feet long and one and a half inches interior diameter; one end is closed with a rubber diaphragm, through which is passed a small rubber tube—the other end is all open. We will rest this about horizontal, and taking a little smoke in the mouth, it will be discharged with the breath into the glass tube; it is first thrown towards the top, but it soon falls, and now see it flowing along the bottom of the tube like water—watch it as it reaches the far end—there, see it fall almost like water.

Fig. 4.



Now, by raising the closed end of the pipe, you see we can pour it all out, and by filling it again and raising the other end, it falls back.

Thus you see that, notwithstanding the extra warmth in the breath, it is heavier than the atmosphere, and falls to the floor of an ordinary room like this, say, when the temperature is from 60° to 70°. This is owing to the carbonic acid and moisture contained in it.

I have varied this experiment in a number of ways, by passing it through smaller tubes and discharging it into the air in one or two seconds after leaving the lungs, and by passing it through water of various temperatures, and discharging it into rooms of different temperatures, with the same general results. As the temperature of the air diminishes, the tendency of the discharged breath to rise increases. Much care is required in conducting these experiments,

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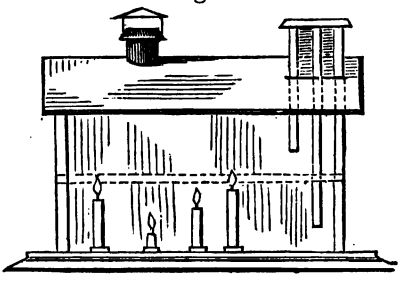
to avoid as much as possible, the local currents which are always present in a room.

This is a very important fact to be borne in mind; yet notwithstanding this, there are times, under certain circumstances, in which the foul air will be found in excess at the top of the room.

Fig. 5.



For the further examination of this subject, we have here a little glass-house with glass chimneys and fire-place in the first and second stories.

As the flame of a candle is such a beautiful emblem of human life, we will remove the roof and part of the floor of the second story, and place four candles in our house. They are all of different heights, you see. We will call them a father, mother and two children.

As carbonic acid is that much dreaded poison in our breath, and the heavy portion of it which causes it to fall to the floor, we will make a little by placing a few scraps of common marble in this glass vessel, and pouring over it some sulphuric acid.

It is now forming, and will fall and flow across the floor the same as carbonic acid does when it pours into a basement from the gutters on the street or filthy yards where it is formed, and before it is absorbed or diluted by the current of pure air sweeping over them. It first kills the smallest child, because it is nearest the floor. You remember the excessive infantile mortality in this city in 1865. This is partially owing to their breathing more of this foul air near the floor, and partially owing to the great fear of their mothers and nurses, of letting the little innocents get a breath of fresh air for fear it will give them colic, and consequently they smother them to death.

The other child dies next, and then the mother, and lastly the father.

Thousands are thus poisoned to death by their own breath every year. But did you ever see a physician's certificate that gave you any such idea? Why do not the doctors tell the living, in such language as they can understand, what killed their friends, so they may avoid it in their own case, instead of giving it in some Latin terms which I fear many interpret to mean some special dispensation of Divine

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Providence instead of the true cause—their utter disregard of the laws their Creator made for the preservation of their health?

Had this family known enough about ventilation to have kept the fire-place open, with a little fire in it now and then, they would not have been thus killed.

Let us see—we will take out the fire-board which has been put in to make the room look a little neater, and with a very small light there to create a draft in the chimney.

We will again light the candles, and pour in the poisonous breath. Ah! there goes the little one—he is hardly high enough to keep out of that deadly current flowing across the floor.

We shall have to let it in a little slower, or we will set him on a platform, as many persons who have carefully studied this subject, consider it judicious to do. Now, by the smoke from this taper, you can see the air is flowing across the floor and up the chimney.

There has been a steady current flowing in long enough to have filled the house, but the lights are all burning brightly, and you thus see the value of an open fire-place for ventilation. Thousands of lives are thus saved, and many more would be if all fire-places were kept open. I have recommended hundreds of fire-boards to be cut up for kindling-wood, as I consider this is the best use that can be made of all fire-boards.

Never stop up a fire-place in winter or summer, where any living being stays night or day. It would be about as absurd to take a piece of elegantly tinted court-plaster and stop up the nose, trusting to the accidental opening and shutting of the mouth for fresh air, because you thought it spoiled the looks of your face so to have two such great ugly-looking holes in it, as it is to stop your fire-place with elegantly tinted paper because you think it looks better.

If you are so fortunate as to have a fire-place in your room, paint it when not in use; put a bouquet of fresh flowers in every morning, if you please, or do anything to make it attractive; but never close it.

Now, there are other conditions in which a fire-place or an opening near the floor, will not answer for ventilation. This occurs in rooms where the air is made impure by burning lamps or gas, and where the fresh air entering the room is cooler than the temperature of the room itself.

To illustrate this, we will put the roof on and take the entire floor away, or as it will be a little more convenient, we will represent it by this glass-house, using this shade for that purpose.

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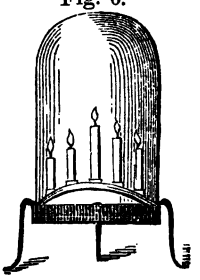
This is supported some six inches from the floor, and has no bottom. By lighting another candle and standing it outside, you can judge by comparison, of the foulness of the air inside.

Fig. 6.



The tallest one is effected first, this time. You see that is a perfectly formed light, but it gives but about half the light the one does on the outside; this is the way with many of us who are obliged to, or rather do, breathe foul air half the time.

We often think, by comparing ourselves with others around us, that we are pretty fair specimens of humanity, while really we do not give more than half the light in the world that we ought to do, and kill ourselves before our work is half done.

You see the two tallest are dead already, and the others will soon follow—there they go. Here is the bottom of the house removed, and yet these candles all went out for want of fresh air.

Therefore, when we see the air is made impure by burning candles or gas lights, owing to its exceeding heat, the foul air is mostly at the top of the room, and especially when the fresh air enters cooler than the air in the room. We will find, however, that in a very few minutes the candles will relight long before the contained air or the glass shade cools down to the temperature of the room.

The products of combustion, like those of respiration, are heavier than the ordinary atmosphere, and consequently fall to the floor very soon if not removed while very hot, by special openings immediately over them in the ceiling; after it has thus fallen, provision must be made for its removal from the level of the floor, in connection with the foul air from the breath.

I hope that by these few simple experiments, and the statistics presented here this evening, we have strengthened your previous convictions of the importance of fresh air, because we are well aware that you will find, as you proceed in your investigations of this subject, that it is frequently surrounded with complications; yet the laws governing the circulation of air of different temperatures, are as fixed and immovable as the laws governing the rising and setting of the sun, and with a very little careful investigation, can be easily understood.

And we believe no similar amount of money or thought, will produce a greater amount of satisfaction than the increased health, strength and happiness thus secured.

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LECTURE II.

As I stated in our last lecture, much interest is being awakened, in this country and in Europe, by recent investigations showing the enormous numbers of untimely deaths that are caused throughout all classes of society by foul air.

It would have been a startling announcement, ten years ago, to have stated that impure air caused as many deaths, and as much sickness, as all other causes combined, and yet the most diligent and accurate investigations are rapidly approaching that conclusion.

Few really comprehend the immense pecuniary loss, to say nothing of the amount of suffering, that we endure by this extra and easily preventible amount of sickness.

I propose, this evening, to enter upon the consideration of one of the most important parts of our subject—*the effect produced by* HEAT *upon the movements of air.*

I think it probable that many of us do not comprehend the actual reality of the air.

We are apt to say of a room that has no carpet and furniture in it, that it has nothing in it, while, if it is full of air, it has a great deal in it.

A room between twenty-seven and twenty-eight feet square contains one ton of air—a real ton, just as heavy as a ton of coal. Now, there is not only twenty-seven feet, but more than twenty-seven miles of air piled on top of us. The pressure of the atmosphere at the level of the ocean is about fifteen pounds to the square inch. An ordinary sized man sustains a pressure of about fifteen tons, and were it not that this pressure is equal in all directions, we would be crushed thereby.

We must accustom our minds, therefore, to consider air a real substance, and that it is as totally unable to move itself, or to be moved, without *power*, as water or coal. It requires just as much power to move a ton of *air* from the cellar to the second story as it does a ton of coal.

Heat is the great moving power of air. Those whose attention has not been especially directed to the subject of the amount of power exerted by the sun's rays upon the earth, have little conception of its magnitude.

The power of all the horses in the world, added to the power of all the locomotives, and of all the immense steam engines in all the

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world, express but a small fraction of the power exerted by the sun's rays upon the earth. It is estimated to be sufficient to boil five cubic miles of ice-cold water every minute.

His rays are the chosen power of the Creator for moving all matter upon the globe. It is his rays that lie buried in the vast coal fields beneath the earth. His rays cause every spear of grass to grow, rear the mighty oak, form the rose, burst its beautiful buds, and send its perfume through the air.

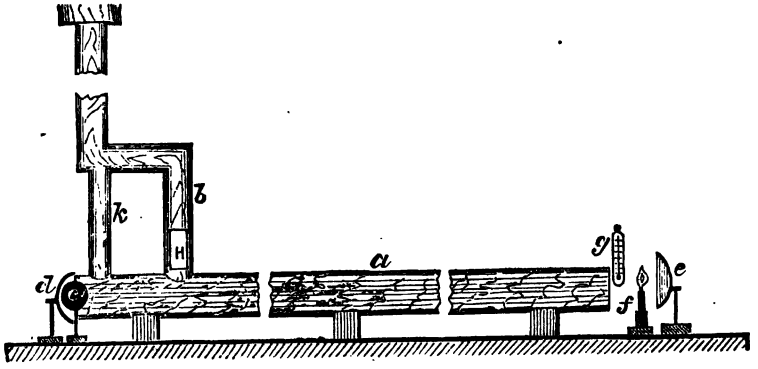
No bird warbles its sweet music in the air, no insect breathes, save by his power, and all animals love to bask in the genial glow of his light and heat. He rolls the scorching air of the tropics to frozen lands, and wafts the ships across the seas. He forces the heated waters of the equator to the poles, tempering all the earth. He lifts the water from the sea to sprinkle all the land and cap the distant mountains with eternal snow.

Now, let us examine a little more minutely how this influence is exerted upon the *air*, which is the subject we are especially interested in at present.

Does it commence at the top, and heat it, layer by layer, until it reaches the bottom? Not at all; but it passes through the whole forty-five miles of air, heating it very little, if any, and falls upon the solid substances at the earth's surface, heating them, which, in turn, heat the air by its individual particles coming into immediate contact with those solid hotter substances.

We will endeavor to illustrate this in a crude way.

Fig. 7.



Here we have a tin tube, *a*, fifteen feet long and ten inches in diameter, open at both ends; two feet from one end we introduce this

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ascending pipe, *b*, the upper end of which is merely inserted in a small flue, extending to the top of the building. The height of this flue is sufficient to make a current of air pass through this tube, as you will see by holding this smoking taper at the far end. We will now place a large heated ball, *c*, at this end, and outside of that we will place this reflector, *d*, pressing it quite close to the end of the tube, so that no air can enter here.

The rays of heat from this ball, or from any other warm body, are thrown like rays of light, in every direction equally; there would, therefore, be some of the rays thrown through this tube to the other end without any reflector, but the proportion that would reach the other end would, of course, be small.

We therefore collect those going the other way, and change their course, and then send them straight through the tube to the far end.

We will place another reflector, *e*, at the far end, to receive and concentrate those rays, in the focus of which we will place a candle, *f*, with a little phosphorus on it, to show you that the rays of heat are passing through.

There you see the candle is lighted, thus proving that there is a strong current of radiant heat coming from the hot ball, through the tube to this end. And you see by this smoke that there is a current of air passing the other way.

Now, we want to know how much that air is heated in passing the whole length of this tube against that shower of radiant heat, or whether air absorbs radiant heat at all; but, before going to the other end, where the hot ball is, we will take two thermometers that have been lying here, side by side, both indicating a temperature of 69°. One of them, *g*, we will hang at this end, about opposite to the centre of our tube, which, I think, will give us a fair average of the entering air, first removing, however, the candle that has been lighted, and the reflector.

We will hang the other thermometer in the ascending tube, at the end near the heated ball. We have had two glasses, H, inserted here, so that we might observe what was going on within. By the smoke from this taper you see there is a strong current of air passing up the tube, all of which must come from the far end, flowing against the strong current of radiant heat going in the opposite direction. Now, leaving this thermometer to rise or fall according to the temperature of the air flowing through, we will go to the other end and examine another very interesting part of this experiment: it is the

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manner in which the radiant heat is received and appropriated by different substances.

Radiant heat is thrown from a hot body in every direction equally, but no two kinds of substances receive those rays of heat in the same manner, nor do they make the same use of them after they have received them.

Every substance receiving heat, however, must give a strict account of it. It must give out an equal amount of heat, or, what is taken as an equivalent, some action or power.

I have a sheet of ordinary tin, and as I hold this polished side behind this light, you see it throws a belt of light across the room; and as I put it in front of the end of our tube, and turn it so that the rays of heat will be reflected in your faces, I think some of you will be able to feel the reflected heat. The rays of heat are turned from their course, and thrown in a belt across the room, similar to the rays of light.

But you cannot give away and keep the same thing. This bright polished surface appropriates but a very small portion of the radiant heat. A thermometer hanging for some minutes against the back has scarcely risen one degree; but we have given the other side a coating of lamp black, with a little varnish, and by turning that side towards the pipe, the result will be quite different. By this coat of black varnish the whole character of the sheet of tin is changed. The black, however, has but little to do with it; if it were white, or red, or blue, the formation of the surface being similar in every respect, the result would be the same almost precisely.

Instead of acting merely as a guide-post, to *change* the *direction only* of the rays of heat, as before, it now becomes a receiving depot, absorbing nearly all the heat that comes to it. It must soon become filled, however. The thermometer hanging at the back has risen six degrees already, and is going up rapidly; it must soon begin to distribute its extra stores. But mark the different manner of distributing the heat. Instead of *reflecting* the whole all in one direction, as when received on the other side, it now *radiates* them equally in every direction.

Some solid substances allow the rays, both of heat and light, to pass directly through them without either reflecting or absorbing them. Other substances allow the rays of light to pass through them, but absorb much of the radiant heat, like clear glass.

Rock salt is one of the best non-absorbents of radiant heat, allowing nearly the whole of the rays of heat to pass through unobstructed.

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We will now return to our experiment at the other end of the tube. I find there is something wrong here—the mercury in the thermometer has risen several degrees. I knew this was rather a crude arrangement for illustrating this very beautiful and interesting part of our subject, but I hoped it would assist me a little in conveying to you the idea I desired to impress upon your minds. I find, however, that it is scarcely delicate enough to illustrate perfectly what I wanted to show.

But this increased temperature is not owing to the effect of radiant heat on the air coming from the far end, for I find by the heat at the top of the pipe, between the heated ball and this ascending pipe, *b*, and by the current of heated air on the side next the ball, that there is a current of *circulating air* that *has been heated* by coming into immediate *contact* with the hot ball.

I designed this smaller tube, *k*, to carry off the air thus heated, but it appears to be too small.

We ought to have had a piece of rock-salt to have closed the end of this tube, so that the radiant heat would have passed through without allowing any *circulation* of *heated air*, but I was unable to find such a piece. But Professor Tyndall, in his lectures before the Royal Institute of Great Britain, gives the results of a large number of very accurate and beautiful experiments tried for the purpose of determining whether the forty-five miles of atmosphere surrounding the earth absorbed *any* of the sun's rays, and if so, how much?

These experiments prove, in the most conclusive manner, that dry pure air is almost a perfect non-absorbent of radiant heat. Thus, were the air entirely dry and pure, the whole forty-five miles through which the sun's rays have to pass, would absorb a very small fraction thereof, so that in the length of our tube it would be but an exceedingly small fraction of one degree, that is, for pure dry air.

But is the air of this room pure and dry? Very far from it.

Professor Tyndall found that the moisture alone in the air of an ordinary room, absorbed from fifty to seventy times as much of the radiant heat as the air does. Air and the elementary gases—oxygen, hydrogen and nitrogen—have no power of absorbing radiant heat, but the compound gases have a very different effect; for instance, olifiant gas absorbs 7950 times as much as air; ammonia, 7260; sulphurous acid, 8800 times. Perfumes, also, have a wonderful power of absorbing radiant heat.

The moisture in the air, however, is of the greatest practical

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importance in various ways. It is the great governor or regulator or conservator of heat; it absorbs it and carries it from point to point and into places where the direct rays of the sun could not get; it is like a soft invisible blanket constantly wrapped around us, which protects us from too sudden heating or too sudden cooling.

Professor Tyndall, speaking of the moisture in the air, says: "Regarding the earth as a source of heat, no doubt at least ten per cent. of its heat is intercepted within ten feet of its surface." He also says: "The removal for a single summer's night of the aqueous vapor from the atmosphere which covers England, would be attended by the destruction of every plant which a freezing temperature could kill.

"In Sahara, where the soil is fire and the wind is flame, the refrigeration is painful to bear."

And in many of our furnace-heated houses, we have an atmosphere very similar in point of dryness to that of Sahara, but more impure.

The foregoing remarks in regard to the impossibility of heating air, apply especially to radiant heat. Air does become heated, but in a different manner; it is heated by each individual particle or atom coming in immediate contact with some hotter substance. See what a wonderful provision for creating a constant circulation of the air. The sun's rays pass through it without heating it, but they heat the surface of the earth at the very bottom of the ocean of air; this, in its turn, heats the air by each individual atom coming in immediate contact with these hotter substances, expanding them so that they must rise, thus enabling the colder and heavier particles to rush in and take their places. With this great universal moving cause, in connection with the innumerable minor causes resulting from the very different absorbing, radiating and reflecting powers of various substances, it becomes almost impossible for the air to be entirely and absolutely at rest, even in the most minute crack or cranny, or bottle corked air-tight.

Now, to apply these principles to every-day life, to the heating and ventilation of our houses, taking the *open fire* first, we find that it acts like the sun, heating exclusively by direct radiation. The rays of heat fall upon the sides of the room, the floor and ceiling, and the solid substances in the room, which thus become partially heated, and in their turn become *secondary radiators*. This radiant heat from the fire does not heat the air in the room at all, but the air becomes partially warmed by coming in immediate contact with the sides of the room, the furniture, &c.

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One great reason, therefore, why an open fire is so much more wholesome than any other means of artificial heating, is because it more nearly imitates the action of the sun.

The rays of heat fall upon our bodies, heating them, while it leaves the air cool, concentrated and invigorating for breathing. The bright glow of an open fire has a very cheering and animating effect. It produces a very agreeable and healthy excitement.

It is not improbable that future careful investigations may prove that there is an important change takes place in the electric or ozonic condition of air as it passes over, or in contact with, hot iron, which does not occur to the air of a room heated by the open fire.

The air in a room heated by an open fire can scarcely become stagnant, because that fire must necessarily be constantly drawing a considerable amount of air from the room to support combustion, the place of which will be supplied by other air, and here is where one of the greatest inconveniences arises in the use of the open fire; if the air entering to supply this exhaustion comes in at a crack of the door or window, on the opposite side of the room, and that air is cold, say 10° or 15° above zero, it flows across the floor to the fire, chilling the feet and backs of those sitting in its track. It is quite possible to roast a goose or round of beef in front of a fire, while the air flowing by it into the fire is freezing cold. This should be remedied by having the air flowing in partially warmed before it enters, say to a temperature of 40° to 50°, either by having the halls overflowed by partially warmed air, and opening a door into it, or by admitting the air to enter around the back of the fire-place, as Dr. Franklin arranged it.

Thus, while an open fire is the healthiest known means of heating a small room, and should be in the family sitting-room of every house, and in offices and other places where the occupants are at liberty to move closer or further from the fire at pleasure, yet it is entirely unsuitable for a large building, or for rooms where many persons are assembled, and have fixed seats, similar to a school, lecture-room, factory, &c.

A stove in a room heats both by direct radiation and by heating the air that comes in immediate contact with it.

But our latest styles of elegant new patent gas-consuming air-tight stoves, require so small an amount of air to support combustion, that there is a strong probability of the occupants of a room thus heated smothering to death for want of fresh air, sooner or later, and generally the former.

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But a stove, if properly used, creates a comfortable and wholesome atmosphere, and is one of the most economical means of heating now known. There should always be a separate pipe for introducing the fresh air from the external atmosphere, which fresh and cold air should be discharged on or near the top of the stove. And if this supply of fresh air is abundant, with a constant evaporation of moisture sufficient to compensate for the increased capacity therefor due to the additional heat given it, and an opening into a heated flue near the ceiling, to be opened in the evening when the gas-lights are burning, or when the room is too hot, and kept shut at all other times, with another opening into a heated flue on a level with the floor, which should be kept *always open* to carry off the cold, heavy foul air from the floor—a stove thus arranged for many small isolated rooms, makes one of the most economical as well as most comfortable and wholesome means of heating at our command. It combines the three great essentials necessary for comfort and health—*warmth*, partially by direct radiation, *fresh air* and *moisture*. But neither the open fire nor the stove, as desirable as they may be in many small rooms, are suitable for large rooms, especially where many persons are assembled. Heating principally by circulating warmed air, or in combination with direct radiation from exposed pipes filled with steam or hot water, is in such cases more convenient.

It is in connection with this system of heating by circulating warm air, that the erroneous views in relation to ventilation generally entertained by the public, produce the most injurious effects.

The special points to be borne in mind in considering this subject are that, when in motion, warmer air rises and colder air falls; but when at rest, the stratums of air of different temperatures arrange themselves horizontally.

One other thing: we must remember *temperature* has nothing to do with the purity or impurity of the air. The pure air entering a room is *sometimes* colder than the average temperature of the room, and falls to the floor, forcing the warmer, and, in that case, fouler air to the upper part of the room.

But frequently, in winter, the fresh air enters *warmer* than the average temperature of the room, and *rises to the ceiling*, and flows across the room above the colder and fouler air that has been longer in the room. You must not forget the experiments in our first lecture, showing that the breath in an ordinary room, of a temperature of 70°, fell to the floor instead of rising to the ceiling. I propose

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illustrating this part of our subject, by using a little glass room to show the movements of air of different temperatures. We can either use air of different temperatures, showing the motion of the various currents by a little smoke; or, as the laws governing the circulation of liquids of different densities are so similar, and by the use of a little coloring matter will express to an audience of this kind more promptly and clearly the ideas which we wish to convey, we therefore propose using the different colored liquids this evening.

The colors, of course, have nothing to do with the densities, but are merely used as a convenient method of designation; the red representing heat or rarity, and blue, coldness or density.

The room is now filled with clear water, slightly blue, to represent cold, and a little salt, which makes it a little more dense than fresh water. Now, I will let in at the top a little fresh water, colored red by cochineal, to represent heat, and by making a similar opening on the opposite side for its escape, you will be able readily to see in what direction it moves. There, see it entering—see how it flows directly across the top of the room, and escapes at the opening on the opposite side. You see it disturbs the lower and colder parts of the room but very little. Thus a large flow of pure fresh warm air might be going through a room all day, and be entirely wasted, neither warming nor ventilating it. Fortunately, there are but few buildings arranged in quite so absurd a manner as this. I believe it was tried in the House of Lords, on the erection of the new Houses of Parliament, but, of course, failed. I think they still adhere to it in some of the wards of some Insane Asylums, where they depend, I suppose, upon the excitement of the patients to keep themselves warm and the air stirred up. I also noticed this arrangement in a new building just being finished, a few years since, at Yale College. The architects of that building had probably been impressed with the dreadful effects upon the health of students of the air from our ordinary hot air furnaces, and thought they would avoid all such danger. I think, however, it would have answered their purpose just as well, and been much more economical, to have placed the furnaces at the coal mines, and saved the trouble and expense of carrying the coal so far. I expect they have made other arrangements, probably, by this time.

We will now close the opening at the top for the *inlet* of the fresh warmed air, and open a valve, so as to allow it to flow in at the bottom. We will allow the opening at the top for the *outlet* of the foul(?) air to remain as before, (see Fig. 2, Lithograph plates.) This is

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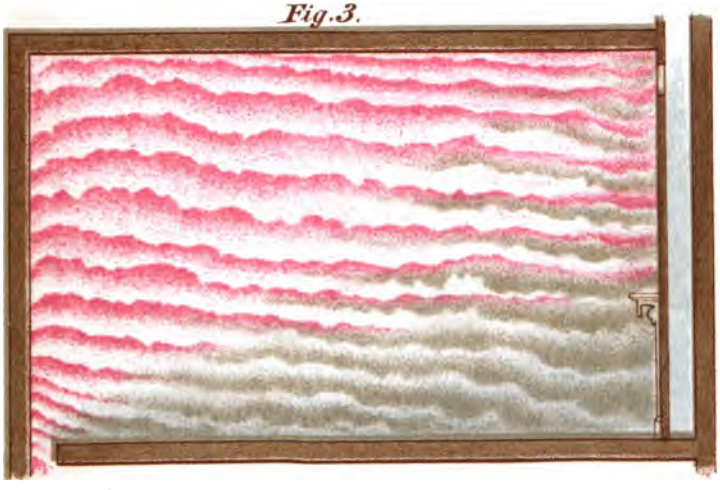
Fig. 1.

Fig. 2.

Fig. 3.



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quite an improvement; it agitates the air much more than the other, and by going and standing directly over the register, you can always get in the current of fresh warm air. But you see to what a very small portion of the room the heated air is confined, rising in one perpendicular column directly to the ceiling, and then flowing horizontally along the ceiling to the outlet. How little it disturbs the main portions of the room, especially the lower and occupied part.

I hope you will notice that this illustrates the popular notions of ventilation. I suppose three-fourths of all the buildings in this country, or in Europe, where any attempts at artificial ventilation have been made, are thus arranged. Dr. Franklin knew better, and made a much more perfect arrangement than this. But we are probably mostly indebted to that very able and enthusiastic advocate of ventilation, Dr. Reid, for this popular opinion. The whole of the plan that he advocated is but little understood by the public. He assumed that the natural warmth of the body created an ascending current around us, and caused the breath to rise towards the ceiling, and consequently, in all artificial arrangements, it was best to endeavor to imitate this natural movement of the air. And to overcome the great practical difficulty we see here exhibited, of the fresh warm air flowing through the room, and disturbing so small a portion of it, he proposed making the whole floor one register, and thus have an ascending column over the entire room. For this purpose, the floors in the Houses of Parliament were perforated by hundreds of thousands of gimlet holes, and the whole cellar made a hot air chamber. This was a magnificent idea, and, I believe, in some few instances, where fully carried out, has given a good degree of satisfaction; but it is always difficult to adjust the opening and the pressure so as to cause an even flow over so large a surface, and at the same time to be so gentle as not to be offensive to those with whom it comes in contact. But this thorough diffusion cannot be conveniently applied in one case in a thousand. It must necessarily be always very extravagant, as it will constantly require a great amount of air to insure a thorough circulation through all parts of the room. I wish, therefore, most emphatically, to condemn all systems relying upon openings in the ceiling for the escape of the foul air, while depending upon the circulation of warmed air for obtaining the necessary additional warmth. In practice they are universally closed in winter,* for the purpose of keeping warm, and as such openings have been so generally considered the *only* ones necessary for the proper ventilation of a room, and as they had to be

* See Fig. 3, lithograph plate.

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shut in winter, just when artificial ventilation was most necessary, it has created a very strong prejudice in the popular mind against all ventilation.

The result of the advocacy of these impracticable theories by so many able and learned men, (most physicians writing upon this subject have adopted them,) has been the shutting up of many thousands and tens of thousands, till they have smothered to death.

The ravages of consumption and the excessive infantile mortality, and the many diseases resulting from foul air poisons, are in a great measure due to the general advocacy of these false theories. As I have before said, Dr. Franklin knew better than this, and had we been contented to have followed his simple practical advice, instead of being dazzled by the splendid theories of others, thousands of our friends would now be with us who died long since for the want of fresh air.

Now, let us see how Dr. Franklin says a room ought to be ventilated. He says, "the fresh air entering, becoming warmed and specifically lighter, is forced out into the rooms, rises by the mantel-piece to the ceiling, and spreads all over the top of the room, whence, being crowded down gradually by the stream of newly warmed air that follows and rises above it, the whole room becomes in a short time equally warmed." This is the principle upon which his celebrated Franklin stove was arranged. Now, let us see if we can arrange our little glass house so as to illustrate this. We will first fill it with what we call our cold air, and will close the outlet at the top, and take out the fire-board (Fig. 4, lith. plate). You see the warm fresh air rises immediately to the top, as before, and flows across the ceiling, but as it cannot escape there, it forces the cold air down, and causes it to flow out at the fire-place. See how quickly the whole room is filled with the fresh warmed air. Ah! I see I am a little too fast—there appears to be a stratum of a foot or two, lying on the floor, that is not disturbed yet. It flows out at the top of the fire-place, and therefore does not reach to the floor. This is frequently the cause of cold feet and much discomfort.* We will make the opening directly at the floor, (see Fig. 5, Lithograph plate,) and that forces all the cold air out, warming and ventilating the whole room. Here is the whole problem solved in the most beautiful and simple manner. And you may exclaim, as you see the simplicity and perfect working of this, how came any one ever to think of anything else.

Here, again, you see the value of that most excellent and valuable

* Especially when the floor is cold—from a cold cellar underneath.

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Fig. 4.

Fig. 5.

Fig. 6.

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of household arrangements, the open *fire-place;* even without the fire it serves a most important purpose.

We must not forget, however, that there are other circumstances in which it will not do to depend on the fire-place alone for ventilation. Now, by leaving the fire-place open, just as it is, and the room full of warm air, we will simply change the *condition* of the air supplied, and allow cold air to flow in at the bottom instead of the top. (See Fig. 6.) There you see the fresh *cold* air simply falls to the bottom and flows across the floor, without disturbing the upper part of the room at all. It acts just the reverse of the hot air let in and taken out at the top of the room.

Now it is very important for a clear understanding of this subject that we should comprehend distinctly that the foregoing experiments refer *only* to cases where rooms are heated exclusively by introducing currents of warmed air which has been heated outside of the room, but one-half of our rooms are not heated in this manner; they are warmed by heaters immediately in the room, such as the common stove, the open fire, steam radiators, living beings, gas-lights, etc. And then the conditions are very different, requiring an entirely different study and treatment. The fresh air generally comes in colder when thus warmed in the room, and consequently falls to the floor and flows underneath the fouler and hotter air that has been longer in the room. We are also apt to be much deceived by opening a window at the top, thinking the warmed air will go out there, or if cold air should come in it would be at the top of the room and consequently do no harm, whereas it not unfrequently falls like a torrent directly to the floor (Fig. 7), keeping the feet cold while the head is hot, and little children may suffer much with cold in this way while the nurse's head or a thermometer hanging above the fire-place may indicate a high temperature.

So you see we must first determine the *relative* temperature of the air entering the room, as that, of course, must be considered fresher than air that has been longer in the room; if that is warmer than the air in the room, then there should be openings provided for the escape of the fouler air from the bottom of the room. If, on the other hand, the air entering the room is colder than the air longer in the room, then there should be an opening for the escape of foul air from the top of the room (see Fig. 8). All windows should be made to lower from the top, as they are the great natural

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ventilators, and are especially useful all summer, and always at night the whole year.

I have noticed another very interesting feature in regard to the circulation of liquids of different densities; for instance, suppose we fill our little room half full with salt water, and the remainder with fresh water, we will now apply a spirit lamp to the bottom of the room (Fig. 9). As the salt water becomes heated it rises rapidly, yet not to the top of the room, but only half-way, or to the top of the denser liquid, and then spreads across the room horizontally. Thus the salt water will keep up a rapid circulation, and may be heated almost to a boiling temperature *underneath*, and without heating or disturbing the cold fresh water *above*. I have tried some very beautiful experiments of this kind with a number of liquids of different densities in the same vessel. Gases of different densities are probably influenced in a similar manner by the application of heat. And here we see the value of that beautiful law of the diffusion of gases, by which each gas, no matter what its density, is equally diffused in all directions through the other gases, independent of temperature.*

I desire to call your attention this evening to one other distinct system of heating—I mean that very convenient, economical, cleanly, and FASHIONABLE system of heating by direct radiation from steam-pipes.

As steam has become such a common article in all large buildings, both for power and as a convenient means of distributing heat, most large buildings are thus heated; and as a perfectly air-tight building can be very easily heated thus, and as most persons are too ignorant or too careless to provide a separate and distinct supply of fresh air simply for ventilation alone, the consequence is, that this system, thus so shamefully abused, is probably drying up more talent and killing more business men in our cities than any other system in existence. This applies especially to the editorial rooms of nearly every one of our leading newspapers and publishing houses. They use steam for driving their beautiful printing presses, and the heating and ventilation, or rather the entire want of ventilation, in their offices, would indicate that they think that the same power which drives their presses to do the printing so nicely, is entirely sufficient to drive them to write the

* See second lecture, second course.

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Fig. 7.

Fig. 8.

Fig. 9.

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original articles for the printer, and that they have no more need of *fresh air* than their presses.

You may think that I am certainly mistaken that so intelligent a class of the community, who are building such splendid fire-proof buildings, such perfect palaces of iron and stone and marble, as our newspaper establishments are building in New York, Philadelphia, and other large cities, would never make such a blunder as to omit providing the most abundant supply of pure, fresh air to every employé in their establishments, and at all times, both in summer and winter.

Should there be any one present thus doubtful, I wish he would undertake to get any one of our enterprising newspaper establishments to publish in their paper an accurate intelligible account of their system of ventilation, illustrating clearly the known quantity of pure, fresh air delivered within using distance of each one of the editors and employés.

I think he would soon come to the same conclusion I have, that the advice of the minister to his congregation would be very applicable to them—"Always do as I *say*, but never do as I *do*."

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LECTURE III.

In my first lecture, I endeavored to show how much we were suffering from the effects of foul air, and the advantages to be gained by supplying ourselves all the time with pure air. Because we must first feel that there is something to be gained before we will make any great effort towards obtaining a given result.

In my second lecture we considered the general principles governing the circulation of air, the courses of its movements, the manner of the action of heat upon different kinds of substances, which creates a constant, ceaseless motion of the air, in all places, from the minutest corked bottle to the vast currents that sweep over the face of the earth.

Now, having learned the necessity for pure, fresh air, and studied the general laws governing its circulation, let us apply these principles to every-day life. To every-*day* life? I should say every-*hour* life—nay, every *moment* of our lives; for twenty times every minute of our entire life, from the cradle to the grave, do we breathe what ought to be pure air. Is it always pure?

If we breathe one single breath, in the entire day, of *impure* air, it will weaken us, deduct from our capacity to attend to our daily duties, or shorten our lives, in exact mathematical proportion to the amount of impurity in that one single breath. Now, we breathe twenty times every minute, twelve hundred times every hour, twenty-eight thousand times every day, and nothing but absolute and perfectly pure air answers the exact requirements of perfect health.

Well, you may ask, at first thought, if fresh air is such a panacea for all evils, and there is such an abundance of it out of doors, why not breathe it, and always enjoy perfect health?

Think one moment. I eat my breakfast in the morning, generally refreshed by a night of good sound sleep, (for I sleep with my windows open.) Immediately after breakfast, I enter the cars to come to the city. What a smell comes from the car as the door is opened! and unless I wish to incur the displeasure, or provoke the indignation, of almost every passenger, by opening a window, I am obliged to sit in that foul, offensive atmosphere, and breathe the poisonous exhalations from my own lungs, and that from dozens of others, some of them, it may be, badly diseased, (most persons' lungs *are diseased* in this country, from breathing foul air, and many other diseases besides consumption are produced thereby.)

Thus, in one half hour, I have inhaled six hundred times of this

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foul and poisonous air, and the blood has carried it to every portion of my body, so that my entire system is completely saturated, poisoned, yes, thoroughly poisoned by it, from the crown of my head to the soles of my feet.

And thus is the day commenced. Your blood is thoroughly poisoned before your breakfast is digested; for your breakfast will no more digest without pure air than the coal in your stove will burn without it. You are subjected to headache, dyspepsia, and a half dozen other aches and pains, and are tired out long before night. And thus you are killed long before you would die if you breathed pure air only.

And am I relieved from the difficulty when I arrive in the city?

Start to-morrow morning at the Delaware River, on Arch or Walnut Streets, or any other street, and go to the Schuylkill. Inquire of every individual, in office, store, dwelling or factory, if he knows whether he had pure air to breathe all day, or whether he can tell you, with any degree of accuracy, how pure the air was in the room he occupied for any hour of that day.

I fully believe there is not one in ten—no, not one in a hundred—of the most intelligent men in that entire street, doctor, lawyer, architect, or any other, that can give you an accurate account of the condition of the air breathed during any one hour of the day. That is not all. There is scarcely one in a hundred that can satisfy you, by an intelligent description, of the means used for providing it:

First—Assuming the air outside to be pure, that there was a constant, positive and sufficient supply of that outside air introduced.

Secondly—That that pure air was not deteriorated by overheating, or contaminated by being mixed with the poisonous gases of the burning coal.

Thirdly—That there was sufficient moisture added to it to compensate for its increased capacity for moisture, due to its expansion by the additional heat given to it, (which is a very important thing.)

Fourthly—That there was any accurate, positive means provided for insuring the fresh air to be brought within reach of the lungs of those for whom it was intended.

And, lastly—That there was a positive means provided for the removal of all the poisoned air thrown from the lungs, so that none could possibly be *re-breathed.*

No; you will find them in close, unventilated offices, in close factories, in almost *air-tight* dwellings. In the large stores they do better.

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The air is very commonly overheated, it is often mixed with impurities, and very seldom supplied with a proper amount of additional moisture.

The air is often so dry, that in a few minutes' conversation the linings of the air-passages to your lungs become parched and husky, producing irritation and a feverish condition of the system. And even in this room, to-night, do you see any opening at your feet, connected with a heated flue, for drawing the foul air from the floor as fast as thrown from your lungs? I believe there is not a square inch provided for that purpose.

Or, do you see any escape immediately above the gas-lights, for carrying off the burned air while hot enough to escape? Not one. There are two or three openings, I think, in the back part of the room, just at the ceiling, but for your breath to get there, it must rise and pass by the zone of respiration, and much of it be again re-breathed; and the products of combustion, as we have seen, would cool sufficiently to fall to the floor long before they reached that point.

I take the liberty of calling your attention to this with more freedom, because it does not indicate any special inattention on the part of the Managers. It is not an exceptional case, but it is the rule. It is the popular opinion of the proper means of ventilation.

Go with me, if you please, to that magnificent building, completed but a few years since, at a cost of half a million of dollars, and given by its noble and generous founder to the city of New York. You will notice, inscribed above the entrance, cut in the solid stone, "To the Arts and Sciences." Look in this reading-room—perhaps the most useful and most appreciated of any public reading-room in the United States. See the large numbers of honest, industrious mechanics, snatching an hour from their labors, to look over the current literature of the day. Here, certainly, we shall find the most perfect arrangement for heating and ventilation that our knowledge of the arts and sciences could suggest. Let us see the arrangements for bringing in the fresh air, for warming it in cold weather, and for removing the foul air.

What! no provision for a regular supply of fresh air? Not one foot, not one inch—neither are there any regular flues for the removal of the foul air. And this most remarkable condition of things is but repeated in the magnificent hotels, marble palaces used as offices, and in many of the new and splendid colleges; and, we might almost

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say, in all other buildings throughout the length and breadth of our land.

Thus you see how difficult it is for one to mingle freely in the society of his fellow-men, under existing circumstances, without being subjected to being poisoned by foul air. In going from here to my home, to-night, I shall have to ride in those cars, the air of which I dread more than I ever dreaded the small-pox or cholera. I have been in hospitals where I have seen much of both. They may slay their thousands, but foul air its tens of thousands. And it is only when I get to my room, where I shall probably sleep to-night with two windows well open, allowing the unobstructed breezes of half a mile of open country to sweep through my chamber, that I shall feel entirely secure from the contaminating influences of foul air, and enjoy to its full extent the greatest of God's temporal blessings to man—*pure air.*

I have no new patent idea to present to you, which shall secure to you at all times perfectly pure air, without any further trouble on your part. There are no two constitutions precisely alike, any more than there are two human faces, or two handwritings, and there are no two hours in our entire life in which all the physical conditions of our body are precisely the same. It would be just as absurd, therefore, to go to a ventilating establishment, and tell the proprietor to ventilate your house or office, and pay the bill when it came in, and content yourself by saying: "Well, I am glad this ventilating business is done with. I have got my house ventilated, and the bills paid, and I am glad I am *through* with that vexatious business." I say this would be just as absurd as it would be, in case you had some pain or ache, to go to your doctor and get some medicine, and therewith content yourself, and say: "Well, I am glad this doctoring business is over with; I have been dreading it all my life. I have been to the doctor's at last, have been doctored, and got my medicine and paid my bill, and so I am through with that vexatious business."

No—you must first feel that fresh air is worth taking some trouble to obtain. You must then make it a *study how* to obtain it without *chilling* or *overheating* your body, in winter and in summer, at night and in the day time, when you are lying down and when you are sitting up, before eating and after eating, before exercising, while exercising, and after exercising—when you are well and when you are sick, when you are alone and when you are in the crowded cars, or in a crowded room, in wet weather and in dry, and for the ever

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varying changes of the external atmosphere—all these conditions require separate and intelligent thought.

In summer we depend almost exclusively on the natural movements of the air. To cause the air to *move* is then the great matter. We must then remember that the great masses of air move horizontally, not perpendicularly. Of course, there are many little disturbing influences, but I mean the great mass of the air moves over the surface of the earth in horizontal strata. You can see this by the smoke of the locomotive on the prairie, which can be seen sometimes for twenty or thirty miles, stretching along just above the horizon. All *flues*, therefore, are of little account in summer. We must depend on open doors and windows. Suppose you wish to ventilate your room in the morning, the air outside having become a little warmer than the air inside, and the upper parts of the window only lowered: the warmer air would flow across the top of the room, leaving the air undisturbed in the lower and colder part. In this case, the window should be raised from the bottom, or a door opened that would afford an escape for the air.

But again, suppose this same room to want ventilating in the evening. The room has become warm through the day, and the outside evening air is cooler than the room, and then, if you raise the windows from the bottom only, the cooler air will flow across the bottom of the room, leaving the upper part undisturbed and foul.

No doubt you have all noticed, frequently, that in going into a room in the evening, when your heads were above the window opening, it would be quite hot, but if you stooped down below the line of the open window, it would be cool and pleasant. All windows should be made to lower from the top, to meet this special case. If you are boarding, or are so unfortunate as to be put in a room where the great blunder has been made of not having the windows to lower, go to the nearest carpenter shop next morning, before breakfast, and get a chisel, and cut six or eight inches off the little strip which supports the sash, and, with a gimlet, bore a hole directly through the sash, on both sides, and with a nail you can keep the sash up in its place, when necessary. I have had hundreds, yes, I suppose, thousands, made to lower this way in the hospitals.

Motion, motion is the great desideratum in summer. You have all noticed, no doubt, how pleasant it is to go into a cool room, like a parlor, that has been kept shut up on a hot summer's day; but in a short time it begins to feel oppressive, and it is more comfortable to

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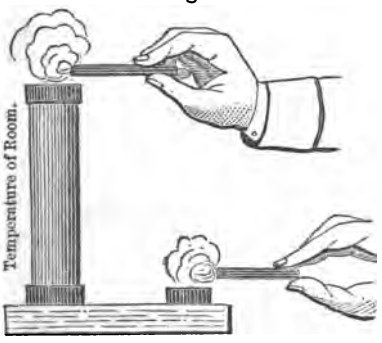
have the windows open, and a *circulation* of air, even if it should be a little hotter than the stagnant cool air.

Never sleep with closed windows in summer. It is in winter, however, that the greatest care is required in providing a constant supply of pure air. If we would but accustom our minds to comprehend, readily and quickly, that cold air falls and warm air rises, it would assist us in our conclusions. We all know that, of course, but we do not practice *applying* it readily and quickly on all occasions.

In summer, as I have said, the air moves horizontally, and then windows and doors are the great means of ventilation; but as cold weather approaches, we must keep the windows shut, excepting when in bed. In winter, therefore, we must resort to flues for the means of creating a circulation, and for conveying the air from one part to another. A flue is simply a passage—a communication—for air of different temperatures. A flue has no power to *create* a draught. If the air within is colder, it will have the power to fall; if warmer, it will be driven up.

For illustrating this, I have here some glass tubes about two feet long and two inches diameter. This one (Fig. 8) has been lying on the table some time, and I suppose is very nearly the temperature of the air in the room. I have here a little tin box, which answers for a connecting tube, and over one of the openings I stand this tube, and by the smoke from this taper, first held at the top, you see there is no current down the tube. And again, by holding the taper at the lower opening, you see there is no current passing up the flue. But I will remove that, and place one (Fig. 9) over the same opening that is warmer, and now you can see how strongly the smoke is drawn down through this lower opening, and see it flowing up this warm flue, and out at the top.

Fig. 8.



We will now substitute a cold flue (Fig. 10). This condenses the air, and it falls rapidly. This action often occurs in the spring and early part of summer, especially in the morning, as the external air becomes heated, and the solid mason-work of the chimney remains cold, causing a descending current, which is often noticeable by the smell of soot

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in the room. We will now add this tube, of the same temperature as the room (Fig. 11), to see if the additional height will not make an ascending current. But you see the smoke is still drawn down, the

Fig. 9.

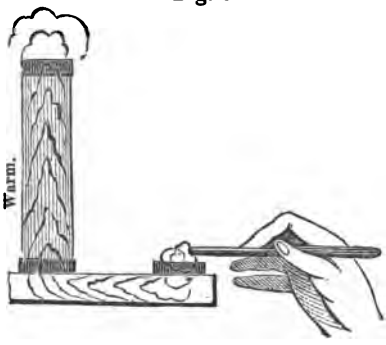
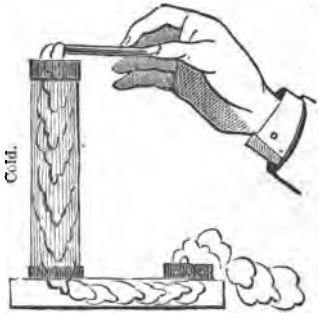


Fig. 10.



height of the flue adds a little to its power, but the difference in its temperature is the controlling force.

We will now place another tube over the lower opening (Fig. 12). Just see what a wonderful effect that has! Here is the air rushing

Fig. 11.

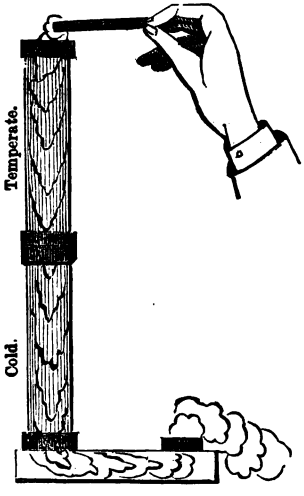
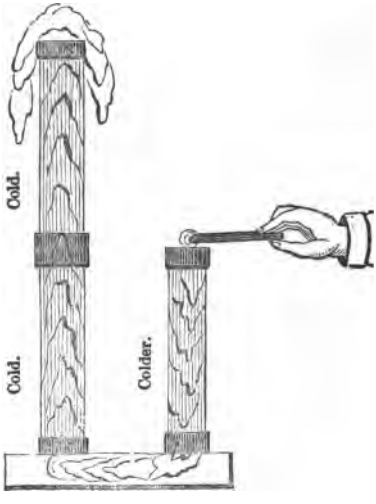


Fig. 12.



down this short flue and up the two cold ones. We called those two first pipes cold, but our ideas of heat and cold are simply *comparative;* everything is warm, or has heat in it. Perhaps some of us think there is not much heat in the air when it comes whistling around our ears 15° or 20° below zero; but the cold rigid chemist will still

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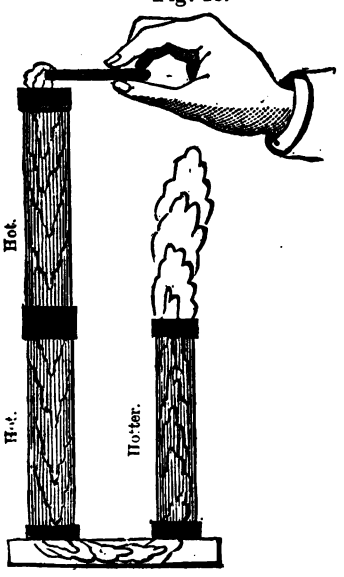
extract many degrees of heat from that. We must, therefore, remember that absolute temperature has nothing to do with the air passing up or down a flue—it is simply *comparative* temperature.

Let me show you one more experiment. Here are two tubes we have had heated; as you see, the smoke rushes up them rapidly. But now we will add this third one (Fig. 13), which reverses the current at once. The two first are hot, taking the *temperature of the room as the standard*, but the third one is still *hotter*.

Fig. 13.



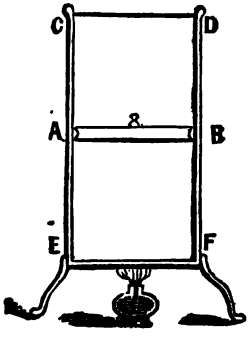
The form of a flue has but little to do with the draught; the height has a slight influence, but bear in mind constantly that the great moving power in all flues is the variation of temperature.

Now, let us make a practical application of this principle.

Wait a moment: just let us lay this one aside, but not forget it, as we shall want to refer to it in a few moments, and try another experiment which has some bearing upon the subject.

I have here a tube just one foot square and two feet long, and one foot from the bottom there is what we will suppose to be an air-tight piston that can be moved without friction. Now, suppose we heat that air 490° (for the sake of easy remembering, say 500°); this would just double its volume—it would then be two cubic feet in size instead of one.

Fig. 14.



Now, suppose that, instead of letting this air expand, we should put a weight on it, so as to keep it in its place, how much do you think we should have to place on? Two thousand one hundred and sixty pounds, or about one ton. Now, what do we find these 2160 pounds to represent? It is the weight of a column of atmosphere with a base of one foot square, or fifteen

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pounds multiplied by 144 square inches—it is the weight that would rest upon the piston if all the air was taken out from under it. Therefore, if you add about 500° of heat to a cubic foot of air, it makes it two cubic feet of air; or, if you attempt to keep it from expanding, you must put a ton weight upon it.

Mark one thing, however, if it takes ten ounces of coal to heat that air to 490°, which we do by piling our ton weight upon it, it will take fourteen ounces of coal if we allow it to expand to two feet.

In the former case, where the air remains stationary, it had done no work. It was ready to go to work, but it had not commenced. But in the case of its expansion, it had done a great work. What was it? Why it had lifted that ton of atmospheric air one foot in height, and that work was what used up the difference between ten parts and fourteen parts of coal (I don't trouble you with fractions).

You see, therefore, to make the air quit the earth and ascend into the upper regions, requires a positive power, the same as it does to drive some poor simple people away from the fire on a cold day.

We often say that, by heating air, we give it power to ascend; instead of which heating it destroys its power to maintain its position. It weakens—enervates it—so that its neighbors easily drive it out and take its place.

One cubic foot of air, diluted to two feet, would be driven about two miles and a half high before it found any body as weak as itself, for every 350 feet in height, in round numbers, the pressure diminishes by an amount equal to one degree, or forced under water thirty-four feet reduces it to one-half its bulk.

Now, let us go back and finish our syphon, or flue experiment.

Here we have our little glass house again.* We will take the roof off and put a pretty large family in it—I mean large in numbers, if not in size. You may call it a school, or public meeting, or church, or whatever you please. Suppose, for illustration, we call it a church, and we will call this larger light in this end the minister speaking to the congregation. You see, the lights are a good deal agitated, and flare around a good deal.

There is a rush of air down at this end, and, as it becomes heated, it rises at the other. Let us cover about one-half of this up. Now see what a rush of air there is *down* these flues, instead of *up* them, as there ought to be. Here, you see, the main body of the building, though much shorter than the flues, forms the heated leg of the syphon; and you may thus recognize why many of the ventilating

* Fig. 5, page 25.

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flues, put in the cold outside walls of many of our large buildings, persist in working the wrong way, and cold air blows down there, instead of the foul air going up.

But there seems to be too much draught. Let us put the roof on. Ah, that is better; but, then, what a draught there is down this chimney-flue. Call the sexton, and have that stopped up quickly, or those sitting near there will soon catch their death of cold, and will never come here again.

You see, however, they shine very brightly, notwithstanding all the draught, but there, now, it is all closed up as snugly as the most fashionable church in town. See how quiet and peacefully they burn now.

Ah, there is one just gone to sleep. You must excuse him, he probably was up most of the night with a sick child. And there goes another. I think he must have been very busy for the last week settling up his last year's accounts. Just see, they are going to sleep so fast, I don't think we can pretend to give excuses for them all.

And, now, is not that a brilliant congregation to be preaching to? Every one dead asleep excepting the preacher himself, and I suspect he feels stupid enough to go to sleep, but it would not look well; and he has to tax his energies so severely he will hardly get over it, so as to be good for anything for the balance of the week.

You may think this an exaggerated representation of the real facts. Do not deceive yourselves. A few months since I was requested by one of the congregation to visit a building within a few minutes' walk of this place, and see if there was not some defect in the ventilation. The gentleman stated to me that he sometimes attended the class-meeting, and would be glad to go oftener, but it was held in the basement story, and it was quite impossible for him to keep awake, as he had to get up and go out two or three times during the evening, to get a little fresh air, or he could not keep awake.

I examined it. The ceilings were low—only nine or ten feet;—then there were two old leaky portable furnaces, which were used as occasion required for heating the large room above, or the basement room when the class-meeting was held.

The only ventilation they had was to let off the surplus heat (if they had any, which was seldom) into the room above.

Now for fresh air. By a very careful and minute examination, I discovered a little pipe (I think it was about six inches in diameter)

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to each stove (both of which would not be over half as large as what I have to supply my own bedroom), for the supply of the fresh air for that whole congregation. *Fresh air*, did I say? Well, let us see where this fresh air comes from. The janitor, after taking us down and showing where he kept the ashes, wood, old benches, and all sorts of rubbish, was about going up, but said I, "Where is the part where you get the fresh air to the furnaces?" "Oh," he said, "he could not get to that, it was such a rough place, and there was a sewer or gutter (from the adjoining graveyard I suppose) running right across it." And from that place, too rough to be got at, with an open sewer running through, and too foul to go into, was where they got the *fresh air* (!) from for the whole of that congregation to breathe.

And do you suppose this is an exception? Let me tell you. During the first year of the late war I was called upon by the Sanitary Commission to examine the hospitals in Washington City with reference to their ventilation. A large number of the churches in that city were used for hospital purposes, and many of them were heated by hot-air furnaces, and in not *one single instance* had they fresh air boxes to them, neither had they any means for carrying off the foul air. The furnaces were generally placed in a hole excavated under the main part of the building, and all the ground around them left exposed, and the air was sucked in from the fermenting, decaying vegetable mould under the building. And this place around the furnace was the place where all the filth and old rubbish was thrown to get it *out of the way*, and it was thoroughly out of the way too, for the surgeon in charge or any inspector never got there to see it. In some cases I found this space around the furnace used as the dead house!

Did I say there was no attempt in any of those buildings for systematic ventilation? I ought to have made one exception.

I called one morning about ten o'clock at one of the finest new churches, which was then being occupied as a hospital, and asked for the surgeon in charge. He had not arrived. (They did not often venture in before eleven o'clock, the wards became so foul during the night it took till that time, with the windows up, to get them fit for the surgeon in charge to venture in.) I inquired of the wardmaster how the building was ventilated. "Oh, very well—very well, indeed—they had good ventilation," pointing up to a large, splendid ventilator in the ceiling. "Do you keep that always open?" I asked. "Oh, certainly," he replied. But I always have a great suspicion

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of those ceiling ventilators, as they are generally shut. So I walked around the ward, and when under it asked him again if he thought that was open. A smile came over his face as he discovered, for the first time, it was a handsome fresco painting on the solid wall. And this was the only practical systematic attempt at any ventilation in any of the church buildings used as hospitals in all Washington.

I have not been in any of the public schools in this city for many years, but a gentleman told me the other day that he called at one of the fashionable schools up town to get his son and take him home under his umbrella, as it had commenced raining since morning, and as he opened the school room door he was perfectly shocked, as he staggered back from the gust of horrible foul air that came rushing out of that room.

I have examined most of the public schools in New York since I have those of Philadelphia.

They have a way of their own of doing public business over there. There has been a good deal said about ventilating public schools of late years, and as it was such a scientific and fashionable matter they must have their schools ventilated of course.

I was very unfortunate in my intercourse with the Directors of the Public Schools. I did not happen to meet with many of those high toned, liberal, scientific gentlemen that are on many of the committees, of course.

Those beautiful and ornamental gratings called registers are accepted as the external proof of good ventilation, suggesting as they do the flow of an abundance of pure fresh air. So registers were bought freely and put in all the rooms, top and bottom, with splendid red and green and blue tassels, altogether making a handsome show and doing the very able and scientific gentlemen on the School Boards great credit for their enterprise and great care for the welfare and interest of the pupils under their charge.

Now, let us examine the operation of these registers. Holding a handkerchief in front of them, there it remained perfectly motionless. It neither blew hot nor cold—it was perfectly lukewarm, motionless. Go to another—the same. And to another—the same. Well that is singular. Let us go on the roof and see what can be the matter. A careful search fails to discover any flues at all, but a mechanical examination shows that the coping-stone has been put on them, making all the flues as thoroughly air-tight as the solid wall—more perfectly capped than that chimney. There had been no attention

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paid to having the holes for the ventilating flues cut through the coping-stone.

Yes, I believe that to-day a large proportion of all those flues with the elegant ventilating registers at the top and bottom of the room, are capped and made as thoroughly air-tight as the solid wall, and are as perfect shams and as useless as the elegant frescoed ventilator on the solid wall of the church hospital in Washington.

I do not believe that Philadelphians have gone quite thus far in satisfying the public demand for ventilation in the public schools. They may not have *done any more*, but I believe they have not *pretended* to do quite as much.

Excuse me a few minutes; I must illustrate another very great deficiency. The simple illustration I will give you represents almost the universal condition of our hot-air furnaces.

Much complaint was made of the uncomfortable feeling in one of the large public schools, where they had some 1200 or 1500 scholars. I was called to examine it. I asked, as is my usual habit, if they evaporated plenty of water. "Oh, yes; they had given the janitor full directions about keeping the evaporating pans always full." I found the evaporating pans full, sure enough, rather to my surprise, but what do you think they were filled with? Several old brooms, half charred, and some old water buckets all fallen to pieces, and other rubbish thrown in there *out of the way.*

And now those of you who have been trusting to your servants to keep water in your furnaces, if you will take a candle when you go home and go down and examine your own furnaces, you will most likely find them dry, and if you go to the public schools in the morning you will see that they too are not an exception.

I wish I had time to explain the dreadful effect of this want of moisture in all our artificially heated rooms. The air in winter is very dry, the moisture is squeezed out as the water is squeezed out of this sponge. But as you heat it you enlarge its volume again, and it sucks up the moisture just as this sponge does, and if you do not supply this moisture in other ways it will suck the natural moisture from your skin and your lungs, creating that dry, parched, feverish condition so noticeable in our furnace and other stove-heated rooms. Few persons realize the great amount of water necessary to be evaporated to produce the natural condition of moisture corresponding with the increased temperature given the air in many of our rooms in winter.

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I have copied a table expressing in grains troy the moisture contained in one cubic foot of air when saturated:

Degrees Fahrenheit.	Grains of vapor in cubic foot.
10	·8
20	1.3
30	2·
40	2 9
50	4·
60	6·
70	8·
80	10·
90	15·
100	19.

Thus you see, taking the air at 10° and heating up to 70°, the ordinary temperature of our rooms, requires about nine times the moistue contained in the original external atmosphere, and if heated to 100°, as most of our hot-air furnaces heat the air, it would require about twenty-three times the amount in the external atmosphere.

This is a very interesting and important subject, but I am sorry I have not time for further explanation.

I see some kind friend has been around and opened the doors of our meeting-house and awakened the sleepers. And now you see the lights shine, and the cheeks glow as brightly as would those of our young ladies could they be persuaded to go skating, or take a five mile walk every day, rain or shine, and sleep with the windows open, and never ride in any of our cars, or go to parties or any other public gatherings unless the buildings where they are held are well ventilated.

But those dreadful drafts! People will not bear them. Let us see if we can accommodate them. Put on the roof, and here comes this dreadful current again down the ventilating flue. Well, ventilating flues have the name of being great humbugs. Let us shut them up. There are your poor consumptive patients—there they go, you see. One-half dead already, and the rest will soon follow if we cannot rescue them. Let us open the flue again. See how they brighten up as the fresh air comes in. There is no use of disputing about it, you must have *a current of fresh air coming into the house* or you will surely die.

Now let us change the programme. Let us build a fire in this fire-place in the lower story—that burns up brightly. Where does it get fresh air from now? There can be no current down the chimney.

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Let us search it out with this smoking taper. Ah, here it is coming down through the ventilator from the very top of the house. We will soon stop that by this cap.' But see, it still burns as brightly as ever. Let us try again. Ah, do you see the smoke rushing down the second story chimney and across to the stairway, and down the stairs, and across the room again to this fire?

There is a valuable hint. Have you not noticed frequently gas in the room from the fire-place or stove, and especially at night? And do you see how easily it would be to account for it if the house were shut up tight at night, with a large fire in the kitchen or furnace in the cellar, and but a small fire in the second story? Don't you see how the whole products of combustion, all the poisonous gases, may be drawn out into the room? You often notice accounts of whole families being smothered to death in one night, but many seem to think if they are not smothered to death the first night, that it is not so very dangerous after all, and not knowing how to remedy it easily go on from day to day and sometimes escape the whole winter with a little of their lives left.

Now, let us put out the fire in the first story and make one in the second.

You must remember that this is not a fashionable double ceiled and plastered air-tight house. It is much more open, in proportion to its size, than any ordinary house. And now, as this lower flue has been so highly heated, it may take some time for the fire in the second story fire-place to become heated sufficiently in excess to cause the air to draw down the longest flue to the bottom of the house and up the stairs to the second story fire-place, but it will soon do it.

I wish you to notice one thing here particularly, and each one apply it to your own particular case. You know the lower part of the house is closed up tight to keep out the robbers, and if great care is not taken to give an abundant supply of fresh air to your chambers otherwise, it will be drawn up through the hall out of your kitchen and cellar, and as the cook has left the range lid off and shut the dampers, you will have a suffocating smell of gas all over the house. But the worst danger of all is the air that may be drawn in from an untrapped sewer or cesspool. This is a very common but great source of ill-health.

Sanitarians have given much attention to this subject lately, and have been astonished at the magnitude of the evil. I have long main-

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tained that a family might go to the highest and most healthy location in the world, and by a little carelessness might accumulate sufficient filth around them, and by closing up the house at night and allowing the foul gases from untrapped sewers and cesspools to enter through the halls to their sleeping rooms, to thus make what would otherwise be a healthy place a very unhealthy one.

As a case in point, I would refer to a very interesting report of Doctors Palmer, Ford, and Earle, giving an account of their investigations of the causes of a severe epidemic that occurred in the summer of 1864 in a young ladies' seminary in Massachusetts. "The Maplewood Institute" is situated in Pittsfield, one of the most beautiful of those charming New England villages, which, to external appearances, are the very emblem of all that is pure and healthy. Yet even in this lovely place, from an ignorant or careless arrangement of the drains and cess-pools, much of the foul gas generated there found its way into the building,* making sixty-six out of seventy-four young ladies sick, fifty-seven of whom had the typhoid fever and thirteen died. Many similar cases are frequently occurring, some few of which, like this, are carefully investigated, and the causes removed. Many more, however, go unnoticed, and are accepted as special dispensations of Providence, when it is all due to our own negligence.

I want to show you an arrangement that ought to be in every house. We have seen the power of a fire to create a draft, and if you will think a little you will notice that the kitchen fire is the most considerable and most permanent power in ordinary dwellings, and this ought to be made use of to ventilate the kitchen, water-closet and bath-room in every house. But you must not make an opening directly into the kitchen flue; if you do you will interfere with the draft of the kitchen fire, and if you interfere with the kitchen fire you will soon wish yourself at anything but keeping house.

But we can easily get over that trouble. We will use this square glass box again to represent a flue. I don't mean this to represent the size—it ought to be twice that size. In the centre we will put a cold pipe, to show you that a pipe without any heat in it would only cause the foul air to tumble down into the room. Thus you see the smoke descending. We will substitute a pipe with a gas light to heat it.

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* In addition to which there appeared to be a deficiency in the arrangements for ventilation.

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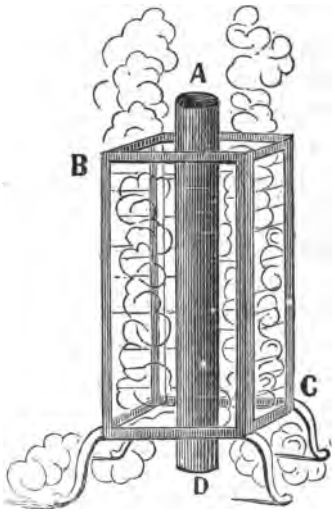
Now you see what a rapid current there is out of this large flue. See what a splendid arrangement this is for ventilating, and it may be extended so as to ventilate the whole house. It is not necessary that the room to be ventilated should be adjoining, but a pipe can be carried between the floors 50 or 100 feet.

Fig. 15.



I had an opportunity, during the late war, of thoroughly testing this system of ventilation in the government hospitals.

Let me say here that a very common mistake in making ventilating flues is, that they are entirely too small to be of any value. One of these little Philadelphia flues, four by nine inches, made with rough bricks, and nearly or entirely choked up with mortar, as many of them are frequently found, is of no account. They are simply a deception, and a perfect provocation to a sensible man.

I commenced by making some in Washington, for single wards, thirty inches square, but in St. Louis, and Louisville, and Nashville, where buildings four or five stories high were used for hospitals, I made them much larger, some three feet square and some four feet by six feet. Some buildings, where the ventilation was so bad and the water-closets were so offensive that the government had to abandon them, I had ventilated by these immense shafts, heated by the kitchen and laundry fires, which proved thoroughly efficient and entirely satisfactory.

I had hoped to have time to discuss the subject of heating more fully in connection with ventilation, but cannot; but I will state, in the simplest manner, a few of the leading points first.

You must have fresh air all the time. In summer you can get it by opening the doors and windows. In winter it must be warmed before entering the room. It must not enter the room cold and flow across the floor to the other side before it reaches the heating apparatus. You can bear a large amount of fresh air if it strikes you in the face and evenly over the whole body, but never let a jet of cold air blow upon any small portion of your body.

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To avoid these local currents sucking in at cracks, you must make provision for the introduction of an amount of air *larger* than the sum of all these cracks, and your exhaust flue besides. This air must be partially warmed before entering. If this is done by a hot-air furnace, it must have a large fresh air box, which should be from eighteen inches to two feet for a large house. It should have a large evaporating vessel, with a ball-cock to supply it. You cannot get the servants to attend to it, and you must never allow the air from your cellar to enter your furnace to be driven up stairs. Never allow the furnace to get red-hot.

A hot water furnace disturbs the natural conditions of the air the least, and, on that account, is a very healthy means of artificially heating air. But they are necessarily expensive, and so few persons really appreciate the value of pure air, that but few will go to the expense of introducing them. It is a mistake to suppose that they do not dry the air, so to speak. You cannot elevate the temperature without increasing the capacity for moisture. A hot water furnace, therefore, requires the artificial evaporation of water to give the warmed air its true hygrometric condition.

Heating the air by steam is the next most healthy means; as the surfaces used are heated a little hotter, less of it answers the same purpose. The first cost is therefore less. It is the most rapid and convenient means of conveying heat to any distant point of anything now in use. Under the pressure of an ordinary boiler it will travel seven miles in one minute. The time I hope is not far distant when the subject of heating and ventilation will receive an amount of attention due to its importance. I believe then we shall have steam pipes laid through our streets, the same as gas and water now are. The present system of each man keeping up separate fires all over his house is as crude, and extravagant, and unnecessary as it would be for every man to make his own gas or have his own well for water.

Where a steam furnace is used, two-thirds of the heating surface should be put below the floor and fresh air brought into it, and from there conducted to the rooms through large pipes. This warmed air should be let into the room at the floor, and an opening into an exhaust flue, two-thirds the size of the inlet, should be provided at the floor for the escape of the foul air. The remaining one-third of the heating surface should be exposed in the halls and some in the other parts of the house, to heat by direct radiation, but under no

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circumstances should a room or office be occupied *heated exclusively by direct radiation* from exposed steam pipes. It is one of the worst, most unhealthy, *killing systems* in existence.*

Steam furnaces require the evaporation of an additional amount of moisture as well as any other system of heating. According to Dr. Wetheral's investigation, it would require the evaporation on some days of nearly forty pounds of water every minute in the Senate Chamber to maintain the proper hygrometric condition. Probably one of the very best arrangements is to have a good steam furnace, with a large fresh air box letting in an abundance of air moderately warmed, and overflowing the house with this, and some direct radiation in the halls, and a good, bright, cheerful open fire in the family sitting-room.

But if you cannot have a steam or hot water furnace, you can make a room very comfortable indeed with a stove, if you will but introduce all the fresh air required for the room directly against or on top of the stove. No stove ought to be put up without having a supply of fresh air from the outside, and a large evaporating vessel, kept constantly filled with water, with an opening in the heated flue near the floor for the escape of the foul air.

In conclusion, allow me to urge upon you to examine your furnace this evening or to-morrow morning, and if there is no fresh air box communicating with the external atmosphere, go to the nearest carpenter's shop before going to your business, and get him to come at the earliest possible moment and put in a good large one, and if he asks you where you want the damper in the cold air box, tell him you don't want any.

Dampers in cold air boxes are handy things to have in the house, when used properly, but, like fire-arms, are very dangerous if you do not understand them. Yes, dampers in cold air boxes and other contrivances for keeping the fresh air out of houses, have killed more persons than all the fire-arms ever made in this country or any other.

If you have no evaporating vessel in the furnace, stop at your furnace man's, and tell him to put in two good large evaporating vessels in such a position that they will evaporate two or three buckets of water a day in cold weather.

And if you have a stove at your office, stop on your way down and buy a good large earthen pan to set on the top of the stove, and keep it always full of water. Make a pipe for the inlet of fresh air to every stove over which you have any control, and never remain

* My views have somewhat changed with regard to heating by direct radiation. See last lecture.

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in a room one day without a good opening at the floor for the escape of foul air.

And from my own experience, and that of many others whom I know to have given much attention to this subject, I can assure you, with the fullest confidence, that you will be most amply rewarded for your care in this respect by increased health, strength and happiness, and by the reasonable prospect of a long life.

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SECOND COURSE,

DELIVERED BEFORE THE FRANKLIN INSTITUTE

DURING THE WINTER OF 1867-68.

LECTURE I.

PERHAPS no subject relating to the health of the human system ever gained favor more rapidly, (without advertising,) than has the subject of ventilation within the last year or two, and I think we may refer to the report of the Board of Health, for the year 1867, as a substantial and most gratifying proof of this assertion.

In the year 1865, there were 17,169 deaths in this city; in 1866, there were 16,803, and in the year 1867, there were only 13,903, or a saving of 2,870 lives in the last year, and 3,237 in the two years, and this, too, notwithstanding an increase of population probably equal to 20,000 per annum.

The saving to the citizens of Philadelphia by this diminished mortality, and the sickness represented thereby, could be scarcely less than three-quarters of a million a year; or sufficient to pay the entire expense of our excellent system of public schools.

Could this decrease in the rate of mortality be continued we would soon be a very healthy people; perhaps this is almost too much to hope for. I do believe, however, that this rate of decrease in the mortality may be continued through the year 1868, and with a cash outlay, if judiciously expended, no greater than will be returned to us penny for penny and dollar for dollar within twelve months thereafter.

No healthy condition of the human frame can be maintained without we breathe pure air, and although there has been a wonderful improvement in this respect within the last few years, yet we still do not breathe pure air one-half our time.

Our arrangements for the artificial ventilation of our houses in winter and at night, are still exceedingly imperfect.

The great majority of our citizens scarcely realize the true value of pure air, or hardly know how to obtain it economically at all times. We need more public education on this subject.

There has long dwelt in the minds of many persons a kind of

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vague idea that ventilation was a good thing in its way; but with nine-tenths of the whole people, the chief concern has been to *obstruct* all circulation of air, to stop all draughts, and thus practically to prevent any *ventilation*, especially in winter.

In the good old days of open wood fires, when, as in our childhood, the real chimney-corner was the family sitting-room, so to speak, or at least, for the children, then, with all the listing of doors, caulking of windows, and filling up of key-holes, there was certain to be still an abundance of fresh air, that would force its way into the room in spite of all efforts to keep it out. But with the introduction of anthracite coal and air-tight stoves, and still worse, steam pipes, placed in the room for heating by direct radiation, the stopping of all draughts that were before so annoying, became a matter of easy accomplishment.

The results thereof have been perfectly frightful, persons have thus unconsciously been smothered to death by the thousands and tens of thousands.

It seemed almost impossible to arouse the public from the quiet, satisfied stupor that followed their great victory over their old enemy—the whistling winter wind. Those that have not gone to their long homes during this dark winter-night of stupor and ignorance, may well rub their eyes in astonishment, as they awake to a consciousness of the dangers they have so marvelously escaped.

The poor man, too, as well as the rich, should feel that he has no truer or more valuable friend on earth than fresh air. His food, though coarse and simple, will digest more fully and quickly with an abundance of pure air. His head is clearer, his chest expands and his muscles grow stronger, as his heart grows lighter, and he goes cheerily on day after day with his laborious toil, returning at night to his home and fireside, surrounded by his wife and little ones, a happy man, made so by the consciousness of having been able to do and having done a good day's work. He enjoys a night of sound sleep, when sleeping with open windows, and wakes refreshed in the morning, ready again to commence the toils of another day.

The Doctor's explanation of the physiological effect of breathing air, whether pure or impure, is very interesting.

We cannot, of course, expect to go into a regular medical or physiological lecture at this time, but we must just examine some of the

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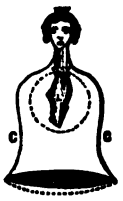
main points so as to get a general idea of the effect produced by air of different qualities, and if possible, to form some conception of the manner of its action. I have here a little arrangement by which I wish to represent the action of the lungs.* It is simply a glass bell jar with a piece of rubber stretched over the bottom, which is intended to represent the human diaphragm. From the mouth of the figure-head there is a small tube extending downwards, and this represents the wind-pipe, at the end of this is another piece of rubber, which we will suppose to represent the lungs. Now, as I draw down the diaphragm, the space in the jar is enlarged, and a partial vacuum is created, and the air rushes down the wind-pipe to fill the space. It is prevented, however, from getting directly into the body by the lungs, which being elastic, or rather all folded up in innumerable little folds, expands and contracts with great ease. The power, therefore, does not lie in the lungs so much as in the diaphragm and ribs, the air is forced out and in the lungs, similar to the manner in which it is forced out and in a pair of bellows.

Fig. 16.



The lungs are composed of an immense number of air-passages, with innumerable branches, we might say, perhaps, like the branches of an apple tree, and at the extreme ends of these branches are air-cells instead of apples. The number of these little cells is estimated by some to amount to six hundred millions.

The aggregate surface of all these air cells is variously stated by different physiologists from 600 to 1500 square feet. So, if this room was 30 × 40 feet, the surface of the lungs of a single person would, if spread out, be sufficient to carpet the whole room.

These air-cells are perfectly surrounded by a complete net work of minute blood vessels, through which flows the dark, impure blood that has just returned from the most extreme points of the body, bringing with it, dead, diseased, old, worn out particles of the body, and the carbonic acid, or what we might call the ashes resulting from the combustion of the oxygen, which is constantly required to keep up the heat of the body.

Now, it is when this impure blood on one side meets the pure air on the other, that the most wonderful change takes place.

This membrane of these air-cells of the lungs is so exceedingly

* Griscom's "use and abuse of air."

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delicate, that there is a chemical transformation or exchange takes place at once.

The carbonic acid, and other impurities from the blood, pass through this fine membrane of the lungs, and are absorbed by the air, while the oxygen of the newly breathed air passes through the lungs into the blood, which is thus changed from a dark color to a bright, light colored red, and oxygen is thus carried to the hundreds of little capillaries in the most remote parts of the body to the skin and to the bones, to the brain and to the stomach, and there burned to keep up the heat of the system, and to cook the food we have eaten, (if the Doctors will allow me to express in that homely manner, the beautiful and very elaborate process in which the fresh air we breathe acts in digesting and utilizing our food.)

But suppose, instead of the air thus introduced into the lungs being pure, it is impure, or already loaded or charged with carbonic acid by previous breathing, then it cannot take up the impurities of the blood, and instead of its being changed by the absorption of oxygen to a beautiful bright red, it remains of a dark, dull color, consequently these impurities have to be carried back to all parts of the system, instead of the much needed oxygen; disarrangement of the whole system soon follows to a greater or less extent, according to the proportion of the impurities in that air.

The little air-cells of the lungs also become choked up with this refuse material, which causes what is familiarly called consumption. You all know if you allow the ashes to accumulate so as to fill the entire space underneath the grate, that the grate will soon be burned out. In a manner very similar to this will that exquisitely thin, delicate membrane of your lungs be destroyed, if you neglect to breathe sufficient pure air to carry away all the ashes from the immense numbers of fires constantly burning in your body.

The frequency of these interchanges between the air and the blood, the very large aggregate amount of each that daily passes through the lungs, ought to impress us with the great importance of a careful attention to maintaining the best conditions for perfect health.

But, in too many cases, our estimate of the value of things is based upon the dollars and cents it costs us, and as no patented monopoly has ever been able to control the supply of pure air, so as to dole it out to us by the dollar and cent's worth; and though it is kept constantly poured around and over our houses in the most lavish

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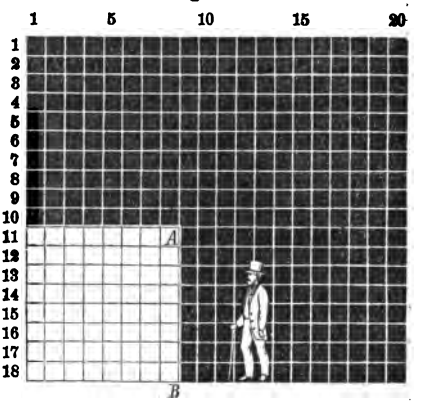
profusion, yet we have in many cases treated this wonderful bounty of the Creator with shameful neglect.

I have prepared a diagram by which I hope to impress upon your minds the amount of air breathed by each individual in twenty-four hours. It is 18 × 20 feet, and intended to represent one foot thick; this gives 360 cubic feet of air, or 125 times the whole bulk of a man. The space included within the outline 10, A B 18, Fig. 17, represents the proportion of oxygen in the air breathed, the whole of the air breathed being indicated by the entire figure.

This, of course, is given merely as an average. The amount breathed varies very greatly from many causes,—some persons may breathe at times nearly double this amount, and at others not half so much. The average number of respirations is estimated at about 20 per minute, and the amount inhaled at each respiration is about 20 cubic inches.

Fig. 17.



We do not completely fill and empty the lungs at each breath, on the contrary, the lungs contain 150 to 200 cubic inches of air, so that about one-eighth only of the contents of the lungs is changed at each breath. I believe Physicians have scarcely determined positively how this air remaining in the lungs is quickly and constantly purified.

The diffusion of gases, which I hope to explain in our next lecture, has much influence, no doubt, in removing the excess of carbonic acid from the remaining air, and saturating the freshly entering air before it is inhaled.

Some physiologists explain, that the carbonic acid and other impurities, are expelled from the minute cells by the muscular contraction of the circular organic fibres, and are thus delivered into the larger branches in which diffusion at once takes place with the air just introduced.

It will be seen by the above representation (Fig. 17) that the proportion of oxygen, which is the very important element in the air, occupies in bulk about twenty-one parts in the hundred, or a

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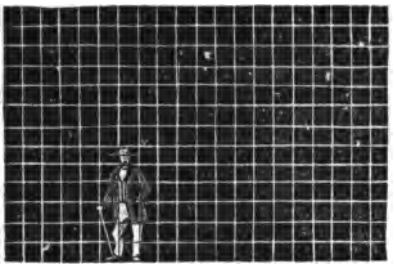
little more than one-fifth of the whole. The other four-fifths being mostly nitrogen. The use of this latter gas, the nitrogen, has scarcely been determined; it is thought by many to be merely a dilutent of the oxygen to keep it under control, so that it shall not take fire spontaneously, and burn everything up.

So much for the air we breathe; the blood, of course, continues the connection from the lungs to all parts of the body; and let us examine that for a few moments.

The beating of the pulse is the action of the heart in pumping the blood from the extremes of the body, and driving it through the lungs to be aerated. There are, on an average, about seventy-two pulsations of the heart every minute, and two ounces of blood are passed through the lungs at each pulsation, or from sixty-five to seventy gallons every hour, and from forty to sixty barrels per day. I designed by this piece of red flannel (see cut, Fig.18) to represent the number of cubic feet of blood passed through the lungs every twenty-four hours.

Figure 18.



We thus see the very large amounts of blood and air that circulate through the lungs, and can easily imagine of how much greater importance the proper supply of air is to the maintenance of good health than the supply of food, because, while we eat less than two pounds daily, we breathe fifteen times that amount, or about thirty pounds.

The amounts here given are only approximations, they are subject to extreme variations.

We all know the wonderful effect of any violent exercise, how it sets the heart to beating, or, in other words, the blood to circulating; this at once requires more air; we begin to breathe faster and inhale and exhale much larger quantities.

It is astonishing how many persons disregard this wonderful provision of nature for keeping off disease, or for curing it after we have, by our own negligence, allowed it to affect our bodies.

The simple difference in the amount of blood and air which circulate through our systems, under different circumstances, shows us what control we have over our bodies in this respect.

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The variation in this circulation from entire repose to vigorous action, may be thirty or forty per cent.—say thirty per cent.—taking the average amount of air breathed at three hundred and sixty-three feet, thirty per cent. of this would be near one hundred cubic feet difference in the amount of the air breathed; and taking fifty barrels as the average amount of blood circulated through the body, thirty per cent. would be fifteen barrels.—Fifteen barrels of blood! coming to the lungs to be purified, to be aerated, and one hundred cubic feet of air, an amount thirty or forty times the bulk of the body, and this the *difference* only, not the actual amount, but just the difference between a state of perfect quiet and that of active exercise.

What a means this is of influencing the condition of the body, and what an incentive to active exertion instead of sluggish, stagnant quiet.

Every child going to school ought to walk at least one mile in the morning and the same in the evening in returning home; and no child ought to see the inside of a school-house, until quite able to walk that distance in all kinds of weather, without any inconvenience. This positive *necessity* for daily exercise is an advantage, as when it can be avoided it is frequently omitted in stormy and unpleasant weather, much to the injury of the child's health.

It is quite a common idea with many persons, that if they feel unwell in the spring of the year, their blood must be out of order, it is impure. Now there is but little doubt but the blood of too many persons is very impure, but how do they attempt to purify it? Why by taking some vile compound in the shape of some patent pills, or other miserable stuff.

What would you do with a servant that would neglect to put coal on the fire, and just when she was in a hurry to get breakfast or dinner, finding the fire was nearly out, to make amends for her negligence, should pour turpentine or kerosine on, making a great smoke and a temporary blaze? and probably, if a little careless in its use, would set the chimney on fire, and run much risk of burning the house down.

Well, now, it is just as reprehensible for you to go on all winter neglecting to supply yourself with pure air, and in the spring find yourself weak, debilitated with impure blood, and your fire nearly out, and then to make amends for your carelessness, take some de-

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testable pills or some of the world-renowned humbugs in the shape of patent tonics, that, according to the advertisements, are a certain cure for all diseases to which "human flesh is heir." And you might suppose from the reading of these advertisements, that they were an entire and perfect substitute for pure air.

I believe I never was quite so foolish as to take a bottle of any such stuff; but I think there must be a great many who do, from the splendid palaces that are constantly being built from the profits on the sales of such trash.

You might, at first, suppose that physicians, and almost every one else, would have learned by this time the best cure for consumption; yet how generally you find persons with this disease shut up in close rooms, breathing very impure air, and taking extra pains not to allow any *draughts* of any kind to enter the rooms.

I say, you would scarcely suppose it possible that such a contrary course should be pursued; but we must remember how short a time it has been since physicians would not allow the patient to follow the dictates of nature, and drink cold water in fevers.

And most of us remember how common it was, but a few short years ago, to take the very life-blood from a sick person, just at a time when it was most needed in carrying off the disease from the system.

It is not in consumption alone, that fresh air is of such great importance, but it is in all the diseases of the human body. You might, at first, think that in amputating a limb ventilation would have nothing to do with the speedy recovery of the patient; this notion, however, would be a great mistake, as ventilation has more to do with it than any other thing.

The surgeons, during our late war, were fully aware of this; they well knew if they amputated a limb that the death or recovery of the patient depended more upon the air he breathed, than any other agent with which they had to deal.

I remember listening with much interest to the Surgeon General's description of a very difficult case of amputation, which he performed in the field in West Virginia. He kept the patient with him, (generally in a hospital tent,) and he was getting along most favorably; but was sent finally to one of the hospitals in Baltimore, which I think was an old hotel; soon after which he died. I heard the surgeons say afterwards that they scarcely could cut off a finger in that hospital but the patient would die.

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They died from impure blood, they died for the want of ventilation, and this is simply the universal experience of every physician and surgeon.

If I were to scratch my finger, ventilation would have more to do with its healing, than all the salves and plasters I could put on.

It is a very common remark that a cut or wound will not heal because "the blood is out of order." Very sensible remark, too, and the quickest way to get the blood in order is to breathe nothing but pure air and plenty of it.

You have often heard of the woman that wanted some whiskey for a sore toe, but on being remonstrated with for drinking it right down instead of using it to bathe the toe, remarked—"It will soon get there." She was not so far out of the way, either, as we might suppose at first; it would soon get there, indeed, and the inflamed and poisoned blood, I was going to say, would do almost as much harm as it does when it gets into the other end of the system; but perhaps that would hardly be possible.

You cannot live without breathing; you cannot live without eating; you cannot live *well* without exercise. These are the three grand essentials for health, comfort and happiness.

The breathing is of more than ten times the importance that eating is. By breathing pure air you can digest more food, and you require more to satisfy hunger.

Some of you may be surprised to hear me assert, that if you cannot get food you would die sooner by breathing pure air, than you would by re-breathing some of the foul poisonous air previously exhaled. I was led to consider this question by the very unexpected results of some experiments I tried last summer with some flies. I took six half-gallon jars, six quart jars, and six pint jars, making 18 in all, into all of which I enticed flies by covering the jar with bread, with a little molasses underneath it. I intended to put two dozen into each jar, but they would not go in just to suit me, so some had 20, some 40 and some 60. Two of the bottles of each size, making six in all, I filled with my breath, and sealed up tight; two of each size I simply sealed tight, but filled with pure air, and the other six, two of each size, I covered with coarse netting, so as to allow of a free circulation of air and keep the flies confined.

It was in summer, and I closed them up at 6 P. M., the sun about an hour high; I observed their condition at intervals of an hour,

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making a note on each bottle. At the end of the first hour those confined in the breath were very stupid, many of them tumbling about from side to side, and none able to fly. Those confined in the pure air were moderately lively, about half of them could fly from side to side, and were just as much at the bottom as at the top of the jar. But a very different scene presented as the others with the circulating air were examined; they were all crowded to the fresh air opening, their feet sticking up through the netting, and there they remained with much persistence. If driven away they would immediately return, and in one, there being more flies than room at the fresh air opening, they had to take turns standing at the window, which reminded me of what I observed at Nashville jail, which was so shamefully crowded and with so little air, that each prisoner was allowed just so many minutes to stand by the little hole that admitted the fresh air, and this was considered so great a privilege, each one waited with the greatest anxiety and impatience for his turn, and they would never miss, night or day.*

So it seemed to be a great privilege with these flies, but I suppose they did not take their turn with so much punctuality.

In two hours some of the flies in the breath seemed nearly dead; the others much the same. At ten in the evening no particular change.

Next morning, at six o'clock, no marked difference; those in the breath a little more stupid, and two or three apparently dead; one or two in the confined pure air about dead, on being put out in the bright morning sun they revived wonderfully; those with the circulating fresh air kept up a perfect humming, and the others revived very much; but few, however, of those in the breath, were able to fly even with this extra stimulus. At ten A. M., I went to town, and at five P. M. returned home. I expected to find all those in the breath dead, those in the confined pure air about half dead, and those in the circulating pure air as lively as ever; but to my utter astonishment and disgust, I found every one of those in the pure air stark dead—not a vestige of life in a single fly.

Those in the pure confined air were about half dead, and nearly the same proportion of those confined in the jar with the breath. But they did not die even in these with that perfect regularity that I wanted them to do.

* I should state, probably, that upon reporting the condition of this jail to General Rosecrans, then commanding, he had it remedied.

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That is to say, where there were twenty in a pint jar, and twenty in a quart jar, and twenty in a half-gallon jar, if those in the pint jar died in twelve hours, I expected those in the quart jar to die in twenty-four hours, and so on; but they did not observe any such regular rules in dying.

But, notwithstanding my great disappointment, I kept the jars and watched them. Those in the breath died a little the fastest; but very soon after I noticed another form of animal life in the shape of maggots, which soon attained the size of the original flies.

Now, as these bottles were perfectly clean and corked air-tight immediately after the flies entered, how did those maggots get there?

Some of these flies lived ten days, (there would be but one or two in a bottle that lingered so long,) the other animal life lingered some three weeks. These bottles, upon being opened, emitted a horrid stench.

But the bodies of the flies confined in the pure circulating air never had the least unpleasant odor, were never touched by any insect, and three months after their bodies were just as bright and clear as the day they died. Thus, those in the foul air lived ten times as long as those in the pure air. Now the practical lesson this teaches is what I before asserted, that when you breathe pure air you live faster, so to speak; you are much more lively; you use much more exertion; but all this exertion requires power, and, universally, power requires food.

Now, these flies in the circulating pure air no doubt used more exertion or did more work in the few hours they were living there without food, than did those which lived ten days—their bodies were so thoroughly used up, there was nothing but skin and bones left.

This explains what might otherwise seem a strong argument against breathing pure air.

We find some poor, delicate creatures living on to be forty, fifty, sixty and even seventy years old, and appear to be a perfect refutation of all regular physiological rules; but what sort of lives *do* they live? They cannot do a quarter of a day's work, they can scarcely eat a quarter of a full ration, and if they have existed to an old age they oft-times have scarcely done the work of a quarter of a lifetime.

And thus we find many poor people living in poor, unventilated

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houses, *exist* sometimes to quite an advanced age, but they are often sick and feeble.

Therefore, when a person finds he cannot earn his living, or if he does earn it he is sure he cannot get sufficient food to eat, he had better imitate the hybernating animals as nearly as possible, and get into some close, unventilated place and lie down in perfect quiet and repose—and not fret at all and he will then be able to get along on as little food as the most angelic of our fashionable belles could desire to boast of.

On the contrary, when persons think they are able to earn their own living and a little more, the more pure air they breathe, provided they have an abundance of good wholesome food and plenty of exercise, the greater amount of physical or mental labor they can perform.

The pecuniary value of health is but imperfectly understood. It was found in England that when a certain portion of the tenement houses belonging to some of the large factories were well ventilated, that the tenants required more food; it cost them more per week to live and supply themselves and families with the necessaries of life.

They consequently could not work so cheaply from week to week as those living in *un*-ventilated houses. This appeared on its face to be a strong argument against the pecuniary value of ventilation. But let us take a more careful view of this. Every animal or machine has its market value—a horse is worth so much in the market, so is an ox and a sheep, and to our great shame we have until very lately had a regular market price for a man and a woman. Owing to even the little intelligence which it was formerly admitted that a slave had over a horse, we would give four or five times as much for a man as for a horse.

A good man before the war was worth from twelve to fifteen hundred dollars, and some two thousand.

The superior intelligence and energy of any one here, and the greatly enhanced prices since the war, in connection with the fact that one man with brains can manage machinery that is sufficient to do the labor of twenty horses, adds greatly to the value of an intolligent man,—or, in other words, any manufacturer or capitalist would be very willing to give $5000 for the services for life of any intelligent, able-bodied man between the ages of twenty and thirty years, taking all the risks of his living, and clothing and feeding him for life.

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Now, that $5000 is the entire capital of many young men. Suppose a large manufacturer wants hands at piece-work, and this young man, say, is just married, and anxious to get along, takes the work just as low as he possibly can; he finds by saving a little in his food, and by keeping his house shut up tight, with an air-tight coal stove he can save coal, and thus at the end of the week can just make both ends meet, or, in other words, can pay expenses.

Now he does not calculate how much of his original $5000 he put into that work for the capitalist—but by the reduction of his physical strength he has used two shillings' worth a day of that capital; twelve shillings a week, forty-eight shillings a month, and so on.

Thus drop by drop does that wealthy capitalist absorb the very life blood. Ounce by ounce are the sinews of this poor man bartered away and appropriated by the capitalist.

He is daily growing weaker as his family cares increase, and in a few years, with a wife and family of small children entirely dependent on his daily labor for their food, clothing and schooling, he finds himself broken down in health with a ruined constitution, and he is then cast aside for another, younger and more vigorous man, who will engage to work cheaper, and can afford to do so by using two shillings' worth daily of his $5000 capital the same as his predecessor.

This arises from the ignorance of these laboring people of the true value of health and of the proper means of preserving it. What is the result?

A nation of unhealthy people must inevitably become a nation of paupers, but a healthy nation will surely become a wealthy nation.

For a proof of this assertion we have only to look to the manufacturing districts of England, as they are amongst the most unhealthy. Could they support themselves if their trade with foreign and newer countries was cut off? Undoubtedly not. And look at New England, what does the census of her manufacturing states give? A very small increase of population indeed.

And the manufacturing wards of this city, too, will show a greater amount of ill health and pauperism, which always go together, than the non-manufacturing districts.

Now, how can this be remedied—by any simple act of legislation? I answer no! Not even the fiat of our Congress, representing as it does, the most powerful nation on the face of the earth,

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could reconstruct society in this respect. No, you must teach the people, the laboring man, the bone and sinew of the nation, the value of health and how to preserve it. The parents then will be but in the prime of life when their children shall have grown to manhood, and they in their turn will be competent to care for their parents in old age.

I want each of you to become a lecturer on ventilation; I do not mean merely to give three or four lectures in a whole year—but to lecture every day of your lives, because there is not one of you here but what has some friend now suffering for the want of pure air.

I want you to go to the home of the laborer, the man that is not here to-night—he whose laborious toil from morn to eve demands rest in the evening, instead of allowing him the privilege of attending lectures.

I have visited many such, and find that a few simple, kindly words of explanation are always gladly received, and frequently have their good effect in inducing them to remove a fire-board in a sick-room, or by putting on an extra blanket, to allow the windows to be opened a little more every night, and thus do a real service to these poor, worthy people, by getting two cubic feet of pure air to enter, where but one entered before.

Could Philadelphians but be fully aroused to the great importance of this thing, the mortality of this beautiful city might be reduced for the year 1868, perhaps even more than it was for the year 1867, because I believe there is no city on the face of the earth so favorably situated for an immediate reformation in this respect as this city, as all the houses are built so isolated, with a window and fire-place in nearly every room: while in New York one-half of the population live in houses of entirely different construction, nearly half the sleeping-rooms being merely dark closets into which the purifying rays of the sun and the pure external air can never enter.

And this is a very serious defect, which nothing but tearing down and re-building can fully remedy; although a good artificial ventilation might greatly improve them. Philadelphia has the advantage in this respect, very decidedly.

If it were in any way possible to get all the physicians stirred up, to make some active exertions towards inducing the people to

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be more careful about the ventilation of their houses, it might have a wonderful effect.

This, however, is hardly to be hoped for, as a regular old school Philadelphia physician is probably about as respectable and proper and conservative a man as the sun shines on. We could scarcely find a greater curiosity than the name of a regular old school Philadelphia physician at the head of a recommendation to public favor of any new thing, no matter of how much public utility it might be.

The surgeons in charge of the splendid hospitals built in and around Philadelphia during our late war, made verbal and written protests against having these hospitals ventilated in winter, because the form adopted by the Government was a little varied (for the purpose of adapting it especially to these temporary buildings) from the time-honored forms to which they had been accustomed from their childhood up. There is one great comfort to you in this characteristic of your regular physicians:—if your doctor was to offer you a medicine you were not accustomed to, do not have the slightest hesitation in taking it, for you may rest perfectly assured that it has been tried in every hospital in the land, and that it is in common use in every other city in the Union before it is offered to you.

It seems to me a little unfortunate that our physicians have fallen into this quiet, easy way of gliding around so elegantly, with their hands in their gloves and their brains in their medicine boxes. Now, this is not because these physicians do not really know better, because, if you were to attend their lectures you would find them discoursing very eloquently on the great importance of the functions of respiration, and the importance of pure air in all cases.

NOTE.—If you should happen to find the Professor lecturing thus in a close, unventilated room, smelling very badly, this, you must remember, is a strong argument of their appreciation of pure air—as you know doctors never take their own medicine.

Or, if you were to go into the office of any one of them, and take up any of the standard text books on their tables, you will find that all eminent medical writers lay very great stress upon the necessity for the most perfect ventilation at all times. They consider it of greater importance than eating, drinking and medicine in the prevention and cure of disease. For instance, here is Carpenter's Human Physiology, which, in summing up a very elaborate article on Respiration, says, page 326:

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"Thus it appears that in all climates, and under all conditions of life, the *purity of the atmosphere* habitually respired is essential to the maintenance of that power of resisting disease which, even more than the ordinary state of health, is a measure of the real vigor of the system. For, owing to the extraordinary capability which the human body possesses of accommodating itself to circumstances, it not unfrequently happens that individuals continue for years to breathe a most unwholesome atmosphere without apparently suffering from it, and thus when they at last succumb to some epidemic disease, their death is attributed solely to the latter, the previous preparation of their bodies for the reception and development of the zymotic poison being altogether overlooked.

"It is impossible, however, for any one who carefully examines the evidence, to hesitate for a moment in the conclusion that the fatality of epidemics is almost invariably in precise proportion to the degree in which an impure atmosphere has been habitually respired, * * * and that by due attention to the various means of promoting atmospheric purity, and especially efficient ventilation and sewerage, the rate of mortality may be enormously decreased, the amount and severity of sickness lowered in at least an equal proportion, and the fatality of epidemics almost completely annihilated. And it cannot be too strongly borne in mind, that the efficacy of such *preventive* measures has been most fully substantiated in regard to many of the very diseases in which the *curative* power of medical treatment has seemed most doubtful, as, for example, in cholera and malignant fevers.

"The practical importance of this subject may be estimated from the startling fact, which inquiries prosecuted under the direction of the Board of Health have recently brought to light, viz: that the *difference* in the annual rates of mortality between the most healthy and the most unhealthy localities in England, amounting to no less than 34 in 1000, is almost entirely due to zymotic diseases, which might be nearly (if not completely) exterminated by well-devised sanitary arrangements. The *lowest* actual mortality is 11 per 1000, while the highest is 45 per 1000, and between these extremes there is every intermediate degree of range. But what may be termed the *inevitable* mortality, arising from diseases which would not be directly affected by sanitary improvements—is a *nearly constant* quantity throughout, namely, the 11 per 1000 of those districts which are free from zymotic diseases.

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"The average mortality of all England, in ordinary years, is about 22 per 1000, or just double that to which it might be reduced; so that taking the population of England and Wales (as by the last census) at nearly 18,000,000, the average annual mortality must be 396,000, of which only 198,000 is *inevitable*, an equal amount being *preventable*."

Thus you see these physicians tell you that one-half of all the sickness and death are "*preventable*." They don't say they can *cure* them with their medicines, but that they are preventable, and that the great means they recommend for accomplishing this wonderful work is pure air—ventilation. But, although they have said this and re-said it, for the last fifty years, yet it has seemed, as Dr. Hamilton has said, a herculean task to make the public at large comprehend it. So that a whole life spent in teaching the value of pure air has seemed to be a whole life almost wasted.

The extracts that I have just read were written more than ten years ago. But the very careful investigations that have been since conducted by many able and scientific hygienists, only more fully prove these assertions. Perhaps no city presents a stronger contrast between her healthy and unhealthy wards than does the city of New York.

Dr. Harris says of one of the most densely populated wards of New York, the Seventeenth, that the death rate has been for several years less than 17 to the 1000, and even during the terrible heat of July, '66, the uniform low mortality of that ward was scarcely affected. The death rate in this ward, with its 27,000 inhabitants, was, during the six months ending October 1st, (including the cholera summer) only 16⅓ to the 1000. In the same period the mortality in the notoriously foul Sixth Ward was 54 to the 1000. And although the death rate of Philadelphia is exceedingly favorable, by comparison with some other cities, as, for instance, New York, where it is about 30 to 33, while in Philadelphia it was but 20 deaths to the 1000 of population, yet, you see even that is nearly double what it should be—that it would only be 11 per thousand if we could only avoid those zymotic diseases, or such as are caused exclusively by foul air poisons.

And I believe with an extra ton of coal for each family, and an extra blanket for each bed, so that every chamber window might be opened, this night, the one-quarter of one inch, to-morrow night two-quarters, and the next night three-quarters, and so on until every cham-

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ber could be kept the whole night in a pure and wholesome condition, and never after closed, we could do much towards saving the 6000 or 7000 lives due to this proper death rate of 11 to the 1000.

But now I have a word to say to you, the people that employ these physicians. They have a good deal of human nature about them after all—they are not so very different from the people amongst whom they live and by whom they are employed. I don't suppose there is a city in the United States in which a physician has to be more exceedingly careful of his *reputation* than in this very city of Philadelphia. And I happen to know something of the reasons for omitting to prescribe, more frequently, fresh air as the medicine most needed for their patients. How many of you, if, being sick, were to have a physician to call frequently, and just say to you, "All you need is more fresh air," would not say, in your mind (if not out of it), "Well, I think I can attend to getting a little fresh air myself, without paying that doctor two dollars per day for telling me that, and I think, upon the whole, I will get some doctor that will do something for me." So you will probably send for some man you have heard of, as having made wonderful cures of some friends, and if he should happen to be a regular shrewd humbug, he would make a wonderful account of your disease, and finally tell you he thought he had something that would just suit your case, and, as before illustrated, would commence pouring turpentine or kerosene oil on your fires, by which he would create a great smoke and temporary blaze, and this would induce you to exclaim, "What a wonderful man! *he* does something;" and if he could get you out into the fresh air, *that* would soon cure you, perhaps, while you would be giving all the credit to his medicine, and the dollars to him for his trash.

I know some physicians, of most excellent good common sense, who have ideas of their own, and independence enough to express them, and have much more faith in good hygienic rules and regulations, who prescribe pure air, pure water, good wholesome food, and plenty of exercise, but seldom prescribe medicine. These men would have to beg their bread if they had to depend exclusively on popular custom for their living.

And now let us take a new start. Let us put our shoulders to the wheel manfully. We have made a most excellent beginning during the year 1867, and our journalists, too, could they be

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induced to give a line or two every day for some good hints as to the value of, and the best means of obtaining pure air, such results might be obtained as would astonish the world, and would give one of the grandest examples of hygienic reformation ever recorded.

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LECTURE II.

THE air we breathe—what is it? Oxygen and nitrogen, the young student will promptly answer. Oxygen and nitrogen certainly; but how many of us really comprehend what these elements are?

We are told that the distance around the earth is *so* many thousand miles, and so many more to the sun, and that the nearest fixed star is a great many millions of miles from us; but it is no matter how many (though the astronomers have stated it all with accuracy), for I believe it is entirely impossible for the mind of man to realize, or in any way to imagine, more than an exceedingly small fraction of that distance. His imagination will, I think, in all such attempts, be very much limited by the greatest distance he may at some time have seen with his natural eyes.

And when the microscopist tells us of the immense number of living beings found in a drop of water, and when we must know that these diminutive creatures necessarily possess—for performing their functions of life—much of the exquisite machinery of the larger animals, how entirely incapable are we of extending our imaginations to any satisfactory apprehension of the minuteness of these things.

Thus, in whichever way we may turn our investigations, we can find no limit to the minuteness on the one hand, nor to the greatness of creation on the other.

Were we to attempt the study of a single blade of *grass*, and endeavor to learn the many combinations of the simple materials constantly surrounding us which enter into its composition; or were we to try to comprehend the power of that wonderful sub-

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stance we call *heat*, its source, and the cause of its undiminished supply, we should find it the study of a lifetime.

Some of the experiments we may show you this evening, may be as familiar to you as the reflection of your own face in the glass, yet they may appear to you in a *new combination*, and possibly suggest to you some new thoughts.

You may have attended a lecture on Chemistry only last night, and have been delighted with the most beautiful and elegant discourse on the all-powerful and wonderful properties of that greatest of substances—Oxygen—and have seen with what ease it could build up and pull down all earthly things that man beholds. Or you may have followed the *Geologist* in his deep and profound researches into the very bowels of the earth, and listened with rapture as he explained the wonderful formations and transformations which these same substances have been undergoing for untold ages. Or perhaps you may have attempted to follow the *Astronomer* in his daring flights of fancy, as he endeavored to explain to you how that wonderful heat and light of the sun are kept up by the millions upon millions of meteors, which, drawn irresistibly from their paths, dash headlong into that great consuming fire.

But this evening, let us concentrate our thoughts much nearer home; let us endeavor to comprehend more fully the most interesting to us of *all* these mysterious changes; I mean that change which is produced in our own bodies twenty times every moment of our lives, by the air we breathe.

I am led to believe that we have not more fully comprehended this mysterious transformation thus going on within our own bodies, than we have truly measured *mentally* the distances to the fixed stars, or the number of days and hours since the formation of the earth, or can compass by our limited reasoning, those powerful influences which have caused the sun to send forth heat and light without measure, for unnumbered ages, and yet the source itself to be undiminished still.

I say, I am led to the belief of this general want of knowledge upon this subject, by noticing daily, and almost every hour of the day, the most intelligent and best educated men and women amongst us, so entirely ignoring the effect designed by our Creator to be produced by this constant breathing of pure and fresh oxygen and nitrogen, as to shut themselves up in *close rooms*, and breathe

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and re-breathe the same air, till it becomes excessively foul and poisonous.

There is no standard of taste respecting things seen. Those which we know produce the most comfort, and give us the most happiness, no matter what may be their form, we consider the most beautiful.

We cannot *see* pure air, and therefore we can scarcely call it "beautiful;" but let us hope that we may so cultivate the imagination, that if we can but comprehend, even in a slight degree, the marvellous effect that it produces on all that is human, we may soon learn to *feel* that pure air was not only among the greatest, but that it was *the* greatest of all the Creator's temporal blessings to his creature, man.

At our last lecture, I endeavored to impress upon your minds, the very large amount of air which was breathed by each individual every twenty-four hours, it being about 350 cubic feet, or 125 times our own bulk.

Now, if all this great bulk was simply *nothing*, or possessed no qualities except what we could discern with our ordinary vision, it might be of little value. Our eyes are the great medium through which we receive information; but, as I said before, we cannot *see* the atmosphere, and so I fear many of us fail to appreciate the true value of pure air on this account. We are obliged, therefore, to explain its peculiarities in a secondary manner, by producing some *effect* that may be seen.

The air we breathe is composed of seventy-nine parts by bulk of nitrogen, and twenty-one parts of oxygen.

The oxygen is the *busy body;* it is the hard working, active substance that keeps up the fires, cooks the food, burns up the trash, purifies the blood and turns it from a dark purple to a bright crimson color.

[Here followed the ordinary experiments of burning sulphur and phosphorus in oxygen, those elements being consumed with great rapidity and brilliancy.] Thus you see some of the effects that may be produced with pure oxygen, which forms about one-fifth of the air, when it is separated from the nitrogen forming the other four-fifths of the ordinary atmosphere. The nitrogen seems to be a mere dilutent to keep the oxygen under control, and to prevent it from burning or destroying everything by fire or rust.

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[A second experiment was here introduced, to show the indispensability of oxygen, and was explained as follows:]

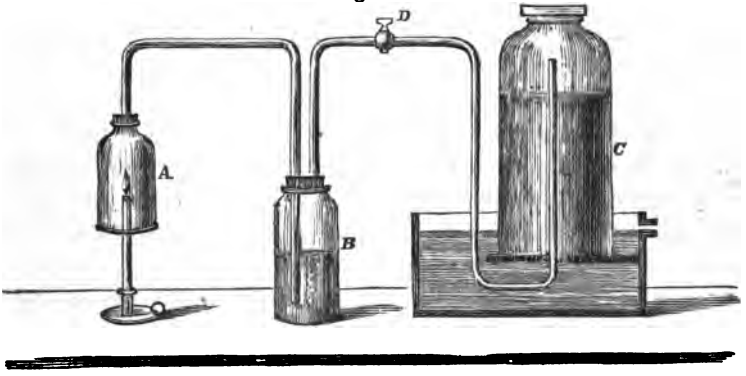
Here we have an ordinary candle, which you see burns just as candles generally do; but now let us place it under this small bell glass receiver (A), and observe how rapidly the flame diminishes in size.

This next glass jar (B), contains lime water, or if it should chance to be Goulard's Extract of Lead, it would answer the same purpose; and you will please notice that it is at present perfectly transparent.

From the top of this wash-bottle we have a connecting tube passing down under and extending up again to the top of this glass jar (C), which is now filled with water.

You see the candle is now almost entirely extinguished, but please note carefully as I open the stop-cock (D), how quickly the

Fig. 19.



candle gets brighter; and you see also the air bubbling up through the lime water, and in the glass receiver the water gradually falling as the air is admitted to take its place.

The candle is now burning as brightly as though it were in the open air; it has all the oxygen it wants, but let me turn the stop-cock so as nearly to close the current of air, the velocity of which you can measure by the bubbling up of the air through the lime-water. See now how the flame of the candle has diminished! Did you ever see such a beautiful way of regulating the burning of a candle? We thus have as perfect control over it as we have over the gas-light. You will notice that the entire bottom of the bell glass is open, and don't forget that when you are burning much gas, you must have—as this experiment teaches—an outlet for the

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escape of foul air from the top of the room. The open fire-place so useful for ventilation during the day, is not sufficient when the gas is lighted.

Ah! see what a change has taken place in this lime-water; it has become white and milky; also, the water has fallen out of the glass jar, as you see, and drawn in sufficient air to take its place.

Now, we are anxious to know what change has taken place in this air. The milky appearance of the lime-water is the chemist's test of carbonic acid; we will therefore assume that that has been caught there, and, as the air has thus been purified again, looks very pure, as seen under the gas-light, at any rate. Let us see now if the candle will not burn just as brightly as in the open air.

Why what can be the matter? It goes out as suddenly as if it were dropped into the water. And for what reason? It is simply because the oxygen is all burned out, and there is nothing but the nitrogen left, and that is entirely incapable of supporting combustion. By looking at this candle, you see we have scarcely burned the little cone at the top, and yet even that has produced sufficient carbonic acid to discolor this bottle of lime-water, and burn all the oxygen out of the large jar of air so thoroughly that it will no longer support the flame of a candle. An ordinary gas-burner consumes as much oxygen and forms as much carbonic acid as five persons.

Now let us see how nearly the burning of the fires in our bodies correspond with that of the candle we have just examined.

First let us take another bottle of lime-water similar to the one we have just used, and by *inhaling* through the short tube, I draw the atmospheric air through the lime-water; but, as you perceive, although I have inhaled many times, there is no discoloration of the contents. I fear, however, if I was to continue much longer drawing the air from this (as I must confess) unventilated room, with all these gas-lights, as well as human fires burning, I would soon produce an evident discoloration; but I will reverse the preceding operation and force my breath through the long tube, and you now see how quickly that causes the same milky appearance which resulted from the air coming from the candle.

Let us proceed now to detach this tube, and by drawing the air out of the glass receiver (c), the water flows in to take its place. Now we will notice the number of exhalations required to drive that water out and fill the jar with my breath,

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and likewise the number of seconds. There, you see it has taken nine exhalations, and required thirty-two seconds, and that jar, as I know, holds six quarts, or one and a half gallons, which would be represented by 346 cubic inches. This is quite excessive breathing, as it would be at the rate of over 600 cubic inches per minute, and you remember we found only 400 the other evening as the average; it may not, therefore, show the ordinary signs of pollution, but let us try it with a candle. Ah! you see it is too foul altogether to support the combustion of a candle.

I wish I could tell you something about the composition of that jar of air; but really, I know nothing about it as I ought to know, nor does any one else. The doctors tell us that one-half of all who die are killed by foul air; but I believe there is not a medical college in the whole country that pretends to teach the careful analysis of this said air. They will spend month after month discussing, and write volume upon volume to prove, that the ten-thousandth part of one drop of medicine will have more effect than a whole spoonful; but as to teaching the analysis of anything quite so common as the air we breathe, that would be too commonplace entirely; so I must simply repeat, we know nothing about it. But there have been a few Germans and Swiss, and some others, who have been able to tear themselves away from the fascinating study of medicine, long enough to make a few preliminary experiments on the more urgently important subject of the air we breathe, and to endeavor to ascertain the effect of the air upon the body, and, reciprocally, of the body upon the air.

From the crude facts that have been thus gathered, we are led to suppose that the proportion of carbonic acid in the exhaled breath, varies greatly under many different circumstances.

Temperature has a very great effect. Experiments have been tried with birds and animals, showing that there is less than one-half exhaled when breathing a temperature of from 86° to 106° than there is when breathing air at a temperature near the freezing point.

The proportion of carbonic acid contained in the exhaled air varies greatly, as does also the aggregate amount; it constitutes from 3 to 8 per cent. of the volume exhaled—probably 4 or 5 per cent. would be the proper average. Hence, as pure air (so called), seldom contains more than five parts of the gas in ten thousand, it

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follows that the breath contains one hundred times the natural quantity found in the atmosphere.

That jar, therefore, contains about one hundred times as much of this poisonous deadly gas, as does pure air, and not only that, there are particles of my body, there are portions of my brain (I don't mean in the sense in which we use it to express the result of thought), but I mean the actual worn out material; and the only valuable substance it originally contained—the oxygen—has been taken out. It is upon the whole a very disgusting mass, as you must admit, and we will remove it carefully, so as not to permit it to escape into this room. I perceive you seem a little amused. I suppose it is at the idea of carrying out that one jar of foul air such as we are all the time exhaling into the same air we *inhale* from; but I think this gives you the true idea of ventilation.

The actual amount of air breathed is comparatively very small; it is only about the one-fourth of one cubic foot per minute. But it is the contamination of the remaining mass that causes the trouble. For instance, as the exhaled breath contains one hundred times as much carbonic acid as pure air does, hence, if one cubic foot of breath was diffused through one hundred cubic feet of air, it would add, even to that very large amount, nearly double its normal quantity.

In determining what amount of fresh air must be supplied for each individual, in a room in which we are each breathing into and from the same general mass, it becomes a question of what proportion of other persons' breath we are *willing* to take into our own lungs. If we breathe but the one-fourth of one foot per minute, a supply of twenty-five cubic feet per minute would give us one hundred times the actual amount of air that passes through the lungs, so that we should then only have to breathe double the normal quantity of carbonic acid.

This twenty-five feet per person per minute, however, is considered by many a large allowance. As low as ten cubic feet per minute for each person is considered by others to be a sufficient quantity, yet even that is much more than vast numbers of our buildings are supplied with, as may be readily judged from the disgusting foul odors noticed in many of them, and which could scarcely ever be perceived if this small allowance even was carefully furnished. Of excretions from the surface of the body in the

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form of insensible perspiration, which are constantly occurring, I have as yet made no allusion.

But now suppose that instead of discharging the breath into the general reservoir, we could discharge it into a closed vessel, as we have done, or by a speaking tube—if I might so term it—or better, a *breathing* tube, directly into a foul air duct, to be carried entirely out of the building; don't you see that one-tenth part of the air that would otherwise be required, would in that case be entirely sufficient? It would then be certainly much preferable to our present arrangements, because we should have radically *pure* air, instead of at best, that which was slightly contaminated.

I don't exactly mean to advise that we should each one carry a long breathing tube in his pocket, and the moment he came into the house, place one end in the fire-place, and put the other in his mouth before he began to talk to you; but I think it demonstrates the true principle upon which we should act, in making our arrangements for ventilation, which is to say—to confine the polluted air—and to remove it as soon as possible from the room. I design showing you in a subsequent lecture that this has been my guide, in the arrangements for ventilations in hospitals, churches, schools, etc., and which, I may add, have been very successful.

It is a curiously interesting fact, that the temperature of the body remains nearly uniform at 98°, under the most extreme variations of external temperature, say from 40° to 60°, below zero, as experienced by Arctic voyagers, to a temperature of from 200° to 300° *above*, experienced by persons accustomed to entering and remaining for some time in furnaces for baking certain wares, and in like employments.

The cooling off, when we are very warm, is caused by the vaporization of the perspiration. A pint of water makes 1700 pints of steam, but as it turns into vapor, or is enlarged like the expansion of a sponge, it absorbs heat very rapidly. Thus, when you perspire freely, or when you see the vapor arising from a hard-worked animal, you may know that the heat is being conducted away rapidly. It is for this reason that the drinking of a cup of hot tea on a warm summer day, by inducing profuse perspiration, has such a cooling and refreshing effect.

But this very fact of profuse perspiration is frequently the cause of what we term "colds;" because, when we are perspiring thus freely from active exercise, and the heat is escaping very rapidly

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from the body, we are apt, when we have an opportunity to rest, to indulge in the agreeable process of "cooling off," wherein the temperature of the body is reduced so much more rapidly than in its ordinary conditions, that almost before we are aware, it is quite below the usual temperature of health. And so it happens that the relaxation of the respiratory organs, and the cessation of the rapid flow of blood, prevents the quick renewal of the heat; or in other words, the fires having been put out by the profuse perspiration, it requires a long time for them to be rekindled, and to get to burning again freely.

There are said to be 2800 little tubes for the escape of the perspiration, in every square inch of one's body, and that the united length of all those in the skin of a single person, is about twenty-eight miles; so that the length of those in *two* persons would reach from here nearly to the Atlantic Ocean. Now, the little valves at the outer ends of these tubes, close very quickly on being exposed to the cold. But as the flow of the current from the interior of the body, does not feel the effect of the cold as suddenly as the valves, it will continue to press forward with its load of impurities, until, being checked from escaping, it will be dammed up near the ordinary places of exit, causing a pressure or inflammation.

To show what powerful effects may be looked for by this sudden stoppage of perspiration, we need only to adduce the fact of the large amounts of moisture which may be driven from the body through the medium of these channels of the skin. A number of experiments tried by Dr. Southwood Smith, on the men working in the Phœnix Gas Works, showed that the average loss of weight per man while charging the furnace or during an exercise of about fifty minutes, was something like three pounds. Just think what an inflammatory effect this enormous pressure, this sudden restraining of the great flow of impure moisture, must produce!

And it is not on the *external* surface only, that this result is produced, but the lining membrane of the air-passages to the lungs is affected even more suddenly, and is also more sensitive than any other. Therefore, we should always remember that the moment we diminish any active exercise, we should immediately, even while much heated, put on an additional garment, or otherwise provide for a very gradual cooling off; being careful that we first cool off *internally*, before allowing the temperature of the external surface to be much lowered.

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The manner of taking cold on leaving a crowded and badly ventilated room, is quite different.

You remember the experiment with the flies that lived ten times as long in the foul air we breathe, as did those in the pure air, and which we attributed to the very sluggish action of all their living functions. Now, when you leave a hot, foul room, although your perspiratory glands may be fully open, and there may be a rapid vaporization from the surface of the body and the air-passages to the lungs, which would not be caused by exercise in this case, but, worse, by the heat of the room, yet the vitiated air that you have been breathing, has not only choked up your lungs and filled your body with the actual presence of much poisonous material, but it has so reduced the circulation that you cannot get up a reaction.

As in one minute after you have emerged into the pure air, you have breathed twenty times, or inhaled 400 cubic inches, the lungs therefore, are the parts most quickly affected. You will frequently feel the inflammation thus produced in your throat, in five or ten minutes after leaving such a room; but you must remember that in ten minutes you will have breathed 4000 cubic inches of cold air. To leave a room such as I have spoken of, and, in place of walking, to sit down in a cold, crowded, foul car, with your back towards the window, is one of the very best possible means, not only of taking cold, but of contracting any other disease to which you may possibly be subject.

The phenomena of a burning lamp or candle is a beautiful emblem of human life. By way of illustrating this part of my subject, I have here a common coal-oil lamp with glass chimney attachment; having lighted which, I will paste a piece of paper over these openings at the base, intended as entrance passages to the air. The evil result of this operation is visible at once; the flame looks bleared and it smokes most miserably; that lamp, to all appearances, has certainly got the dyspepsia!

The food that feeds that flame is simply undigested for the want of pure air—for the want of oxygen—in other words, for *lack of ventilation.*

Similarly, when you eat your full allowance of food, and do not breathe sufficient pure air to warm and purify your blood, your whole system becomes *filled* with undigested carbon or "smoke," as we may call it, the same as with that lamp. Likewise the same

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amount of food will be of less than half its value; just as that oil gives less than half its full light.

One most excellent way to fill your system with smoke, and destroy half your usefulness, is as follows: get up late in the morning, eat a hurried breakfast, and immediately rush to the cars. Sit half or three-quarters of an hour in the close, foul car, and if your feet get thoroughly chilled, all the better for that purpose; a pair of tight boots is the proper thing to prevent the natural circulation of the blood. Have a care to sit with your back to the open window, and your face towards the centre of the foul car; that, too, helps. Your breakfast most probably may not have digested well, and if you feel pretty miserable in about two or three hours, you should commence eating ground-nuts, and keep on at irregular intervals until lunch-time. At this happy period, if you are still a "little under the weather," and not very hungry, go to the restaurant, and eat merely a piece or two of "*home-made pie*," with a glass of milk, nothing more, and I should think that would be about sufficient to keep you up to the American standard of the shameful abuse of health. If there should be anything wanting, however, you might accept an invitation to a party, and after spending several hours in a hot, unventilated room, of course you would be too much fatigued to walk home—in fact your thin-soled shoes and light party-dress won't admit of it—and home you ride in a car conditioned as regards wholesomeness and temperature, as aforesaid.

You may not see at once what connection these physiological explanations have with ventilation; but it is the severest tax upon my ingenuity, so to warm and ventilate a room or car, as fully to meet these imperative demands of the physiologist.

Let me say in a few words, always keep your feet warmer than your head, and your back warmer than your face. I will not say now, turn your back to your enemy, but I *will* say, never turn your back to *your best friend.* Eat heartily twice in twenty-four hours (never more than three times) of good wholesome food, and always after eating sit down for a half or three-quarters of an hour. Remain perfectly quiet in a room ten degrees hotter than the ordinary temperature of that room, keeping the feet warm, dry and free from pressure, and the back thoroughly protected from draughts, with a cool fresh breeze blowing in your face. Follow this up carefully, for awhile, and you will not say you cannot afford the time to spend thus, but you will say you cannot afford to *omit* it.

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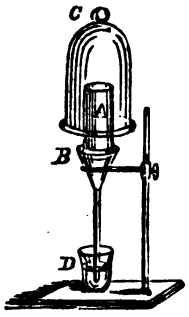
We have here an arrangement by which we wish to explain in a manner the *diffusion of gases;* it has been furnished me by Prof. Albert Leeds, to whom I may say here, I have been much indebted for collateral information and assistance in these lectures.

Fig 20.



It is often remarked that one gas is a vacuum for another gas. This is hardly the proper way of expressing it, because that would seem to imply that a cubic foot of carbonic acid gas would be diffused into a cubic foot of hydrogen gas, both occupying the one space with the original foot of the latter; but this is not the case. They become mixed, however, by exchanging places. For instance, if we take a glass vessel, just one foot square, containing, consequently, one cubic foot of hydrogen gas, which would weigh thirty-six grains, and place it over a similar vessel, containing one cubic foot of carbonic acid, which would weigh 815 grains, or more than twenty-two times as much as the hydrogen, the heavy carbonic acid gas would rise up into the vessel above, and an equal volume of the light hydrogen gas would fall into the vessel below, so that they would soon become equally diffused.

The apparatus which we have here for illustrating this beautiful phenomenon, consists of a glass tube, with its lower end dipping into a vessel of liquid (crimson-colored, so as to allow its movements to be readily seen), and over the top is placed and sealed in position, an unglazed clay jar. Now, into the glass bell-jar which I hold, mouth downwards, we will allow a supply of hydrogen gas to enter, which, as it is about fifteen times lighter than the air in this room, it will readily do, rising directly to the top, and displacing the air. The vessel being filled, as I judge, I will place it over the unglazed jar, and at once you see the air, as it is expelled from the bottom of the tube, bubbling up through the liquid in the reservoir. This is caused simply by the hydrogen gas rushing through that porous clay cylinder, and displacing an equal amount of the air.

But now we will reverse the operation. We will remove the glass vessel previously filled with hydrogen gas, and then, as the porous cylinder will contain a greater proportion of hydrogen than the surrounding air, the excess of the gas will rush back again. This result you see palpably and beautifully demonstrated by the

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rising of the crimson fluid in the tube, and its coursing around the spirals.

Now, this law of the diffusion of gases, is a vitally important one. Did they not possess this property, the different gases would envelope the earth in distinct and separate belts or layers. The poisonous carbonic acid gas being formed in a great miasm near the ground, and being fifteen times heavier than atmospheric air, would cover, primarily, the surface of the earth; then would come a layer of oxygen, next a layer of nitrogen, and so on. Nor would heating them, even supposing the heat should be applied at the bottom, be sufficient to mix them thoroughly, because each density, it would be found, would circulate nearly horizontally by itself.

Hence, it is evident that this becomes an important question with reference to the subject of ventilation; for the reason that, in a still room, although the breath may at first fall to the floor, owing to its having a hundred times as much carbonic acid as ordinary air, yet that would soon be diffused through the whole room. And yet I do not pay so much attention to this, because I think the supply of air ought to be so rapid and abundant, that the slow process of the diffusion of gas would be permitted to exercise but little practical influence.

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LECTURE III.

HEAT is the subject for consideration this evening. Fresh air is the greatest of blessings, and to supply the necessary fresh air, ventilation is, as we have shown, of the first importance; yet we are much more sensitive to heat and cold than to *pure* or *foul* air.

Heat we have to furnish, in a great measure, ourselves: pure air is supplied us by the Creator. Heat is the prime moving power of the air: it is also the great controlling power of ventilation. It is the *improper cold draughts* that make ventilation so unpopular.

Heat, therefore, is the key that unlocks the door for the free flow of pure air, *i. e.*, for good ventilation. Hence, if we desire such ventilation, we must secure the key that unlocks the door where the treasure is kept. And now let us be sure to secure the *right* key.

There are three distinct methods of heating:

1st. *Radiation*—in which the pure, independent streams, called rays of heat, come directly from the sun or other hot bodies.

2d. *Conduction*—or the means of conveying heat through solids, when the particles of the heat are handed from atom to atom. And

3d. *Convection*—which is the condition wherein certain moving bodies, such as air, water, or other fluids and gases, gather up an armful of heat, as it were, and carry it away in their arms to other parts.

Now, it is necessary that we fully and clearly comprehend these three different ways of communicating heat. It will require a little close attention, but the understanding of it is not difficult, and then the whole subject of heating and ventilation, which may now appear as a mystery, will soon begin to look quite plain and simple.

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For the purpose of classifying the different kinds of heat more distinctly in our minds, let us term them according to their relative value, as follows:

Radiant or *Golden* heat;

Conducted or *Silver* heat; and

Convected or *Copper* heat.

This is about the relative value I put upon these different ways of communicating warmth, for our practical purposes. Now let us consider these three several ways of heating, a little more in detail, taking first radiant heat, or our "gold heat," as that is much the most valuable.

There is a tendency to a perfect equalization of that sensation we call heat, in all bodies. If you should bring a block of ice into this room, and a red hot cannon ball, in a little while they would both have become of the same temperature as the room; the ice may have changed form and turned into water, but (no matter for that now,) the colder would have warmed and the hotter would have cooled until all were of an equal temperature.

The rays of heat—like the rays of light from the candle which I have here—are thrown in every direction equally, just as much downwards as upwards, and just as much to the right as to the left.

The special point of interest to us is the effect that the radiant heat has on the air surrounding us. I want you to comprehend clearly that it has *no effect*—it has no direct influence whatever in heating the air. The understanding of this is of great practical value in our study of the subject of heating and ventilation.

This room has air in it, but it is not full, because, by properly pressing it down, we could put in it the air of another room of similar size, and by pressing it more we could add another, and another, and so on until we had got one hundred times as much in it as it at present holds; therefore, we must know that it is not the one-hundredth part full. But now again, if we were to commence at the top, supposing it to be air-tight, of course, and were to remove ninety-nine hundredths of all the air in the room, the remaining one-hundredth part would be evenly distributed over the whole space, so that there would be just as much at the top as at the bottom.

There must, therefore, be some *other* substance or property in the room besides air, and which has the power of separating the particles of air and keeping them equally apart from each other. And

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herein we see exemplified another beautiful provision for the universal distribution of the air; so that should man, or any living animal, happen to be confined in a partial vacuum, yet all the air that is there would be equally distributed throughout that space.

Now, suppose we compress our ordinary atmosphere one hundred times; still the individual particles do not touch each other, as otherwise it would become a heavy solid: it would then only weigh about ten pounds per cubic foot, whereas the same measure of gold weighs more than one thousand pounds. Hence, each individual particle of air must be separated a great many times its own diameter from its nearest neighbor—perhaps, one hundred, or it may be, one thousand times—for any determinate number, in the present state of our knowledge, would be purely conjectural.

Imagine a regiment of soldiers drawn up in line of battle, but instead of standing close together, they were to be posted a thousand times their own diameter, or a quarter of a mile, away from each other—do you not see how many of the enemy's bullets might pass through the *line* without hitting any one? These individual particles of air, therefore, are so far apart that there is very little probability of the rays of the sun, or the rays from any other hot body, striking them; and I believe it is considered that they are *ray-proof*, even against the few rays that might happen to hit them.

Though I cannot illustrate this by showing you radiant heat, yet the rays of light are very similar, and I will endeavor to make the effect evident to you by a simple experiment with this candle. I simply place around the candle an opaque cylinder that interrupts the rays of light that are going directly towards you. But why do you not see the column of rays that is passing directly upwards, and which you can see by that small bright spot on the ceiling? To make it more distinct, I will move the light about a little, and you observe the spot of light moves correspondingly.

Now, the *reason* you cannot see that column of light is because the rays move directly on through the intervening space, having nothing to stop them until they get to the ceiling. I say "nothing," because the air is so near nothing that it allows of no perceptible effect; but now let us interpose something that will stop those rays—this piece of paper, for instance, will collect them, by which the disc of light becomes quite visible—and, of course, being thereby obstructed, they cannot go on to the ceiling. Or, by holding

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this smoking taper in the path of the rays, there is sufficient solid material in the smoke to obstruct a large portion of those rays, and the column thus illuminated is no doubt plainly visible to all.

So you cannot see the rays of *heat*, but they are passing through the same space, and are very similar, in every way, to the rays of light, the difference in the effect produced being considered due to the difference of velocity with which they move.

That smoke will become *heated* as well as lighted:

Experiments have proved that perfectly pure air, and the gases—oxygen, hydrogen and nitrogen—do not absorb an appreciable amount of the sun's rays, and perhaps if they could be made entirely pure, they might be found to be absolutely ray-proof. But you know that the moisture absorbs a great amount of the heat, because a cloud (which is but visible moisture) passing over us of a hot summer's day is an excellent shield from the burning rays of the sun; and there is a large amount of moisture in the air at all times, even when not seen in the shape of clouds.

But you may say, we know that the air does get heated—how is it?

We must again set our imagination to work; we must endeavor to see with our mind's eye those little particles of air, which we at first supposed to be kept constantly separated, and so far apart as scarcely to get within sight of each other, but which, when we come to examine, we find are really clustered together in little groups or families. This we know from the fact, that where we find one atom of oxygen (in the atmosphere), we are sure to find with it four atoms of nitrogen. And again, we find that where these air particles become heated, they are *expanded*, (now a single atom could not expand,) therefore we must conclude that they are associated together, as just remarked, in little groups or families.

The sun's rays pass through the forty-five miles of atmosphere without heating it, but when they strike the solid substances on the earth's surface the temperatures of the latter are very soon raised. We know this by putting our hand on a board fence, or wall, when the sun is shining on it, or on the curtains or blinds inside of the glass window, which become very much heated by the solar rays.

Last winter I placed a thermometer in a box, lined with black cloth, and having put a glass over it to keep the wind off, placed it in a snow bank: the mercury soon rose to 180°. We can boil water by the sun's rays even in winter.

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Now, when these little groups or families, before mentioned, come into actual contact with a hot substance, the heat is transmitted to them *by conduction*—each group, so to speak, receiving its "armful" or complement of heat. Being expanded thereby, they are made lighter and forced upward, whilst other particles rush in to take their place; and these latter, as they strike against the hot body, are in turn heated and caused to rise, so that a continuous stream or current is thus created.

As this will be so constantly referred to in our examinations of the heating and ventilation of buildings, and as we ought to be able to comprehend the principle so as to apply it for the regulation of our own health and comfort every hour of the day, I hope you will fully realize that there are two distinct forces constantly acting in opposite directions near every hot fire or other hot substance. One is, the rays of heat passing in every direction *away* from the fire; and the other is the flow of cold air *towards* that fire, and directly in opposition to the rays of heat.

But, that air is not heated at all until it strikes against the hot body itself. The most philosophical way of roasting a turkey, therefore, is to hang it up in front of a hot fire, and use the golden rays of heat to cook it, while the cold, pure, concentrated air is flowing by it into the fire.

Conducted heat has less influence upon us, perhaps, than either of the other systems. As we are affected in this way only by those things that come in immediate contact with us, of course the better or worse conducting power of our clothing has much to do with our comfort.

But *convected* heat is the great curse of the American people. It is that dry, lifeless, withering, debilitating, poisoned stuff with which most of our best houses and public buildings, and, most unfortunately, many of our school houses, too, are filled and warmed; and which is filling our systems, and warming and drying the life and substance out of about two-thirds of the people of this country.

I have, for the last three or four years, been giving very close attention to the comparative merits of radiant and convected heat.

I formerly supposed that a room warmed by air from a hot water apparatus was as perfect as any artificial arrangement could be, but more careful recent investigations have shown me my great mis-

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take. Let me first say, however, that hot water is probably the most perfect means of warming what *air* we *must* have warmed.

But what I mean to express, particularly, is, that we should be surrounded with and breathe *cold air*, and receive the *heat* required for the body by direct radiation.

This is just the reverse of what we generally experience in our furnace-heated houses. There we have a little hot, dry air—the air itself being hotter than the temperature of the room, and the walls, especially the windows, colder. No more unscientific, unhealthy and uncomfortable condition could possibly be imagined than this.

Our Creator has provided for a constant difference between the temperature of our bodies and the air with which we are surrounded, for a wise purpose; and we find the greater that difference, the more active and vigorous is the action of all our animal functions. As I stated the other evening, there is nearly double the quantity of carbonic acid given off in a temperature of from 10° to 20° that there is in a temperature of 90° or 100°.

From this we would argue that when we are breathing air at this very low temperature, we are twice as active, and can do twice as much work, as when we are breathing air of nearly the temperature of our own bodies. We know how very languid and good-for-nothing we feel on a hot summer's day; and, on the contrary, how fresh and vigorous we feel in the open air of a cold, bracing winter's day, and especially when the glorious golden rays of sunshine come pouring down upon us with all their richness and splendor.

Now, I think we shall be able to apply these *principles* to the heating and ventilation of rooms.

We must study to comprehend the principles, because the circumstances surrounding us are varying so constantly that such arrangements as would suit us best at one time, would not be good at another.

A primary condition to be observed in all heating and ventilating arrangements, as before alluded to, is to keep the feet warmer than the head, and the back warmer than the face.

These are great natural provisions, as in walking, or when in motion we face the current. We inhale from the air in front of us, and the fouled air is carried behind us. For better protection, probably the greater portion of the nerves are concentrated

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FIG. 10.

FIG. 11.

FIG. 12.

FIG. 13.

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near the spine; consequently, if the back is chilled, the whole system is put out of order; and more care is required to keep the feet warm, because, being farthest from the heart, the blood is more liable to become chilled, but if the extremes are kept warm, of course the intermediate parts must necessarily be so.

The sun's rays falling upon the earth's surface, and heating our feet hotter than the air around us, is a beautiful illustration of this principle.

Nearly all animals except man, secure this condition by building their houses, or burrowing below the ground, so that the warmth of their bodies causes the foul air to flow out, while the cool, fresh air to supply its place, must come in from above, and consequently fall upon their heads first.

It must be admitted that most of our arrangements for ventilation and warming do not fully meet these requirements; indeed, a careful examination will reveal the fact that many of them are as absurd and unscientific as they can well be made.

I have here a diagram (see lithograph Plate, Fig. 10), which has been prepared to represent the condition of different parts of the room, when heating exclusively by open fires.

I have been unable to invent or think of any simple method of showing the actual passing or currents of radiant heat.

It is one of the most difficult points to comprehend in connection with the subject of heating and ventilation. It is also one of the most important.

In this diagram, we have resorted to colors to express our ideas. By the blue is designated the strong current of cold air that is usually found flowing along the floor from the windows and doors towards the open fire; and of course the feet and back of those sitting with their faces to the fire, are most affected by this cold air. It may at times be but little above the freezing point; but directly in opposition to this current there is a strong radiation from the bright fire, directly into the face and front of those sitting before it, as represented by the figure of the man in the cut.

We must remember the direct radiation from an open fire or other hot body is not disturbed by the current of air.

Now to get his back warmer than his face, and his feet warmer than his head, it will be necessary to change his position. (Fig. 11.)

I admit, this is rather an awkward position. But you know the conventional way for an Englishman to represent a Yankee, is to have

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him tilted back in a chair, with his feet on the mantel, or in some position higher than his head.

So you see there is a little more practical common sense about this position of the universal Yankee, than would appear at first thought.

Now, I do not suppose this will become a fashionable way of sitting, as represented by Fig. 11, even if the physiologists were to recommend it. But if we want to be really comfortable and healthy, we shall have to change either our manner of sitting, or our manner of heating and ventilation.

Let us consider this open fire question a little carefully, because there are some very good points about it. The heat derived from actual combustion, that is from an open fire, is the purest artificial heat we can possibly have. The temperature of the burning coals or wood is near 3,000°, and the flow of radiant heat therefrom more nearly imitates the sun than from surfaces of a lower temperature.

This is the strongest point in its favor. It is also impossible to prevent its being a good ventilator. And this is no small account to its credit, as it is almost the only ventilation that the people, in their ignorance, do not stop up.

But it also has its disadvantages, which have prevented, and always must prevent its coming into universal use for heating exclusively.

One of these is represented by the diagram in the very uneven manner of distributing the heat, and as it heats the head hotter than the feet, and the face hotter than the back, we shall have to ignore it altogether, or what I think will do better, get some additional assistance partially to warm the air before it enters.

Let us now consider the great abuse of heating by direct radiation without the proper fresh air supply. We have prepared some tanks for using in the lantern, and by using liquids of different colors and densities, I think we shall be able to express to you some of the principal movements of air of different temperatures.

If you will notice carefully, you will soon see that the liquids used to-night are governed by the same laws, and move in almost precisely the same manner, as the air and gases of different densities that we used the other evening.

Professor Morton has very kindly offered to assist me this evening, and has now placed in the lantern a small tank, and by the aid

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of the new Zentmayer prism, shall be able to show you the image on the screen, just in its natural position.

This we could not have done last year, without the aid of this prism, and as we would have had to work everything bottom upwards, I did not then use the lantern for this purpose.

At the left hand corner of our room, (Fig.12), you see the shadow of a small coil, which is fine platina wire. Professor Morton will connect the two ends of that coil with a small battery, and thus put a current of electricity through it, by which it will be heated, and you will very soon see the liquid around that coil (represented by stove in the figure) beginning to ascend. And now you see, as the air around the stove commences to rise, the air from below flows in to take its place, thus giving a revolving motion to all the liquid in the room.

You also notice the figure of a man sitting very quietly, with his back to the window, as though he was in a profound meditation.

We will have to disturb his quiet a little, I think.

(*Here the figure was made to imitate breathing.*)

You see, the breath being loaded with carbonic acid and moisture, falls directly to the floor, and mingling with the revolving mass, will soon be carried quite around the room, and back again to be re-breathed.

This is a combination of warming by direct radiation, and warming the air also by its coming in contact with the stove.

Now please take especial notice of the conditions here represented. This applies to a large number of our ordinary buildings heated by steam, when the coils are placed directly in the room.

It also very nearly applies to rooms heated by air-tight stoves, as there is so little air consumed in them to support combustion, it is hardly worth noticing as ventilation.

The air is already becoming very foul, as it inevitably does, in rooms treated in this manner, when no attention is given to having a regular supply of air.

It allows the room and all its inmates to be sealed up perfectly air-tight. It not only *allows* it to be done, but we generally find that advantage is taken of this opportunity to close all cracks, and it is most zealously accomplished.

There is one other point of much practical importance represented in this: that is, in sitting with the back towards a cold window; the additional warmth or animal heat of the body will be radi-

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ated to and absorbed by this cold window. And thus the very being, life, and vitality will be abstracted, and spinal disease, rheumatism, and all sorts of disorders, are the results frequently of continued sitting in this position. Therefore, never sit with your back to a window. And we must remember the thermometor is a very deceptive guide to go by for ascertaining the temperature of the *air* in a room, as it may be surrounded by air at 100°, yet only indicate 70°, the difference being the loss of heat by radiation to a cold window or wall. And, on the contrary, it may indicate a temperature of 75° while being in an atmosphere of 50°, the difference being the effect produced by the radiation from a fire, hot stove or similar substance. It will be observed, that the cooling of the air by its coming in contact with the window, by no means purifies it.

Now, this is the great *abuse* of direct radiation; the way a large proportion of our buildings and rooms are arranged. I think we can make an improvement on this. (Fig. 13).

In the first place, the heating surface is represented in this case as a coil of steam pipe, but it may be an open fire or stove or any other heating arrangement, and is placed on the cold side of the room and directly under the window, which, being but thin glass, is generally the coldest part of the room.

Now, by raising the window a little, there will be a current of fresh air blowing directly against this heating surface; the entering air will thus be partially warmed. It need not be warmed to the temperature of the room, however, because there will be a large proportion of the heat derived from the direct radiation of the exposed heater.

This gives the very great advantage of having cool, invigorating air for breathing, while the body is warmed by the direct rays from the fire or other heating surface. It also prevents those cold, unpleasant draughts so commonly complained of near windows.

The temperature of the fresh air, too, being so near the required temperature of the room, has no special tendency to rise immediately to the ceiling and escape through any opening that may be made there. On the contrary, being rather cooler, it is first inclined to fall to the floor, and only rises when it is additionally warmed by the persons, gas-lights, heated floor, or some extra warming surface. The ventilators at the top of the room can always be left open without inconvenience, with this arrangement; this, too, is a very great advantage, as they should always

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be open in the evening under all circumstances, to carry off the products of combustion from the lights; and it is so difficult to have them opened in the evening and closed in the day time, with our present careless and indifferent notions about ventilation.

Therefore, an arrangement not requiring this daily attention, is valuable.

This combination of direct radiation and circulating fresh air—partially warmed—with the excess of heat directly under the windows where the excess of cold occurs, is probably as nearly perfect as any arrangement yet devised. Of course, it would add greatly to the completeness thereof to have the floors and walls warmed to about the temperature of the body, to prevent the abstraction of the animal heat therefrom.

The figure represents an additional foul air channel under the floor. The air is represented by the arrows being drawn from the floor of the room around the base-board, and in schools or meeting-rooms when large numbers are assembled it should be drawn from numerous points over the floor. This, frequently, for large, crowded rooms, is an important arrangement.

Of course, these general plans will require many modifications in practice, and much ingenuity may be expended in devising the most perfect manner of accomplishing these important results; but I think these suggestions for reversing the effects of our ordinary method of warming are very necessary to command success, and we had better make up our minds to act promptly, decisively and energetically in endeavoring to bring about the much needed general reformation.

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LECTURE IV.

Since preparing these lectures on ventilation, I have taken occasion to remark to many persons, on meeting them, "I am delivering a course of Lectures on Ventilation; are you interested in that subject?"

I suppose nine times out of ten I receive for answer—"No, I never took any particular interest in it."

Do you breathe? I ask. Looking rather astonished at such a question, they generally say—"Yes, of course," and I ask if they think it makes any difference whether the air they breathe is pure or foul.

"Well, they suppose it does, but they have never thought much about it."

Never have thought much about it! that is the trouble. Now, my opinion is, that it is about time we had thought something about it.

Between six and seven thousand children died in this city, last year, under six years of age—more than half of the whole number of deaths in this city.

Did you ever hear of a shepherd losing half of his lambs by sickness before they were half grown—or a farmer losing half of his calves, or half of his colts? I don't know precisely, but I suppose 3 per cent. would be a full average of such loss, instead of 50 per cent.

Now, what is the cause of this great difference? The shepherd keeps his lambs in the open air, in a great measure, and so does the farmer his calves and colts. But you shut your children in your close, unventilated houses; you wilfully and persistently deprive them of that pure air their Creator has made such wonderful provisions for supplying them with, and has made so essential for their health, and their growth, and their very existence.

You shut them up and smother them in your foul bed-chambers, surrounding them with this poison of human breath—that is too foul to support the combustion of a candle. You poison them to death!

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I have hung on the sides of the room—one on the right and the other on the left—the two lists of tables of the analysis of the air I copied from a report to Congress on the ventilation of the capitol, made by Professor Henry, Thomas U. Walter, and Dr. Wetherall. (The same tables used last year—see page 17.)

The one on your right hand shows the amount of carbonic acid in the open air; and the one on the left, the amount found in buildings.

By an examination of these you will readily see that all external air, such as the sheep, and calves, and colts have to breathe, is uniformly very pure, while that in houses, such as we and our children have to breathe, is very different.

You see here in our scientific lecture-rooms, school-houses, bed-rooms, we have 50, 60, and even 72 parts of carbonic acid in 10,000.

It is that excess of carbonic acid—over 5 parts in 10,000—that represents the foul, poisonous condition of the air of our houses, which is killing half the people of this country.

I consider these tables valuable, because they are nearly all the analyses of air that have ever been made. Comparatively speaking, we do not know anything about that subject as we ought to know.

Let me ask you if it is not passing strange that a great and intelligent nation, like the United States, should so utterly neglect this important subject? A nation that can raise such vast armies, and can raise millions, hundreds and thousands of millions of dollars for destroying each other in time of war, yet scarcely one dollar for analyzing the air and endeavoring to control it and prevent the destruction of human life by that fearful poison—foul air—that killed more persons in the United States last year (a year of profound peace) than were killed on the Union side by sickness, and by the enemy during the entire late war.

If there is a case of poisoning by arsenic or strychnine the whole city is thrown into a state of feverish excitement, and if not suspected until after the body is buried, it is exhumed and the most skilful chemists work faithfully over it to ascertain, if possible, some trace of the poison; and yet, some 3,000 children were poisoned to death in this city by foul air last year, and can you produce one solitary record of the analysis of the air of the room in which they were thus killed?

Is there one of your medical colleges, the boast and pride of this

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city, that teaches its students, by careful analysis of the air, readily to detect and how to remedy those impurities which physicians must constantly meet with in the sick-room?

Shall we not hope that the day is not far distant when the people will be aroused from their dreadful apathy and indifference upon this subject?

We now propose examining the ventilation and heating, as it is applied in various public and private buildings with which you are familiar.

It is not a pleasant task to examine and find fault with the new and splendid buildings that have just been completed, at such great cost, and which are looked upon by their owners and most casual observers as models of beauty and perfection. But, are not these buildings the true index of the general public information upon these subjects? And is it not, therefore, best for all of us that we should give them the most critical examination, and if they are merely showy tombs as it were, and entirely devoid of the proper supply of that life-giving element, *pure air*, to acknowledge the truth promptly and then set ourselves to work energetically to endeavor to learn the best way of improving these, and avoiding such mistakes in all new ones?

THE CAPITOL.

Professor Morton will first throw on the screen a fine view of the Capitol at Washington—this is at all times an interesting building to an American.

And perhaps there is no building in the world upon which there is such a decided diversity of opinion among scientific men as to the perfection of its ventilation as there is respecting this building. I have devoted much time for many years past to studying its peculiarities, and I think if the mere question of a constant supply of air to the main rooms was the only one, it can readily be proven to be well ventilated, and yet it would be very difficult to get any considerable number of the owners who are obliged to occupy the building for a large portion of the year to consent to any such statement.

The universal dissatisfaction is probably owing as much to the quality of the air supplied, and the manner of heating it, as to the quantity.

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I consider this a good example of the ill effects of that detestable system that we as a nation have fallen into, of attempting to warm our buildings by over-heating, and thus ruining all the air used for breathing.

The total absence of any direct radiation is a marked feature, for there is not only the entire absence of any artificial radiation from exposed steam-pipes, etc., but there is the additional absence of radiation from the great natural source of all heat, the sun.

The direct rays of the sun I believe to be not only the most magnificent warming power, but also the greatest disinfecting and purifying power we have, and they are of the utmost value for the vigorous development and exercise of all our physical and mental faculties.

It appears to have been originally designed to exclude the main halls as much as possible from all external influences, and to have all the currents, the heating and the lighting, under perfect artificial control.

But if the whole nation could be taught the valuable lesson, of the great folly of attempting to produce artificial light, artificial heat, and artificially mixed air, that shall be equal to that which our Creator has provided for us, that knowledge would be cheaply bought at the great price paid for these buildings.

This diagram we have here is a copy of a plan made to accompany a report to Congress which was published January 20, 1868.

I tried a large number of experiments during the winter of '67 and '68 to ascertain the direction of the prevailing currents through the Hall of Representatives, and the relative temperatures in all parts of the building. I was rather surprised to find them so distinct and well defined, and also that they were so free from disturbance by the changes in the direction and force of the external currents.

The heat all entering the hall, or passing under it on the west side, gave an additional temperature of 4° or 5°, which was sufficient to cause an ascending current at that end, which produced a corresponding descending current at the other end. A very striking feature was the effect of the exposed copper roof in cooling the foul air and causing it to fall back again on to the floor of the house.

It will be seen by reference to these figures (see diagram) that when the thermometer indicated 61° near the floor, the thermome-

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ter over the glass ceiling indicated 56°, while those around the sides were only 40° and 38°. I found a strong descending current of this cooled foul air descending on three sides, sweeping over the galleries, and tumbling down on to the floor.

This was bad enough through the day, when the air was only polluted by human beings, water-closets, steam-engines, restaurants, etc.; but at night, when the products of many hundred gas-lights were added to it, it became almost insufferable. I noticed that in four minutes after the gas was turned on for lighting in the loft, we perceived it on the floor, and in fifteen minutes it became very oppressive.

I wish to call your attention particularly to this system of ventilating directly into a loft; I find it very often in churches, and in many other buildings where the openings are made directly into this space under the roof, and frequently in schools a whole system of flues will empty into such a place. Sometimes there will be a small blind window in the gables, and sometimes a small ventilator on the roof, but not connected with the ventilating flues.

This is all wrong,—a very deceptive, pernicious system. If there is any circulation, there is almost sure to be a descending current of cold foul air where you do not want it, or very commonly there will be but little or no current at all—and such ventilators will be mere deceptions, much like that handsome frescoed ventilator on the solid wall of the Washington church.

Much care should be taken to prevent the escaping foul air from being cooled down below the temperature of the room so as to cause it to return; the exit pipes should be continued of one uniform size until the foul air is delivered entirely out of the building.

To return to the House of Representatives:—Now, when you add to this revolving and continued resoiling treatment of the air after it gets into the hall, the source from whence it comes, I think we have excuse enough for the complaints of those country members who have been accustomed to tolerably pure air.

Some of the members, who have been lawyers, and therefore obliged to spend much of their time in our court-rooms and city offices, and newspaper editors, seem to be very much at home in such an atmosphere—they may enjoy it.

The fresh! air is taken in through the basement into the cellar, and there forced up by fans through an immense stack of dirty,

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PLANS SHOWING IMPERFECT VENTILATION AND HEATING

HALL OF REPRESENTATIVES WASHINGTON D.C.

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rusty iron pipes, coated by many years' accumulation of rust, particles of decaying animal and vegetable matter, roasted up afresh every day; from thence it is driven through a labyrinth of uncleaned horizontal air-ducts, filled with the moulding and decaying dirt that has collected for years, and finally driven through the uncleaned spittoons (originally intended for registers) arranged all over the floor of the house, issuing into the room at a temperature of from 100° to 120°—a warm, debilitating, filthy, disgusting mass for the members to breathe.

And yet some of the committees, in making very elaborate examinations and reports to Congress, fail to discover any very excessive amount of carbonic acid, and by counting the number of revolutions of the great fan, and calculating how much fresh air ought to be thrown in at each turn thereof, suppose there must necessarily be an abundance of air, such as it is, sent into the building somewhere; consequently they declare it to be the best ventilated building in the world.

But these reports have not generally given very accurate information as to the effect upon the members of breathing air nearly the temperature of the body while being surrounded by cold walls and a cold roof, nor how much of the cooked grease from the engine, or the smells from the water-closets, or gas from the illuminating loft, etc., etc., is mixed up with the air.

As an offset to the very scientific reports proving this building to be the best ventilated one in the world, I might relate an incident that occurred while the building was used for a hospital for wounded soldiers.

On entering the House of Representatives one morning, I noticed a very disagreeable odor, and traced it to a young man with an amputated limb just by the speaker's desk; he seemed in much distress, and the anxious look of his father and mother (I think from Western Pennsylvania) led me to inquire a little after the condition of their son. I soon learned that their special grief was the disappointment in not being allowed to move their son *out of that room on to the porch, where he could get a little fresh air!* They had been promised this privilege the day before, but had been denied it again that morning.

They seemed very anxious to have me intercede for them, and the father followed me out and said, if any money could buy the *privilege* of having his son moved, he would willingly pay for it.

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Can I add any words of stronger condemnation than this touching appeal of a wounded man for the privilege of being removed from this magnificent room to the outer porch that he might get a little fresh air and sunlight?

Here we have another diagram prepared at the request of some gentlemen of this city,* showing some suggested modifications of the ventilation and warming of the Hall of Representatives. It is proposed to draw off the foul air both at the top and bottom.

That taken from the bottom is to be drawn through the present inlet registers, and that from the top to escape around the sides of the glass as at present, and through the illuminating loft to the external air.

Now, with a little ignorance or carelessness it would be very likely to be so arranged that discharging the air in two opposite directions might make confusion, and that it would, at times, all draw up, and the foul air, instead of escaping at the floor, would flow in there; and at other times it would escape at the floor and come in at the ceiling; but it is very easy to avoid such action and with entire certainty.

This is the proper manner to arrange all large buildings intended to be occupied by a considerable number of persons; there should be escapes for foul air thoroughly distributed over the floor, also liberal escapes from the ceiling, and these should be kept constantly open when the room is occupied, and there is no practical difficulty whatever in doing this.

It was originally intended to overflow the hall with the fresh air driven in by the fans; but, practically, this is not the general condition. Several experiments, tried at various times, indicated a strong current setting into the Hall of Representatives from the corridors through every door, both above and below, so that practically the main room is supplied by air from the surrounding passages; we consequently recognize this fact and act accordingly. Arrangements should therefore be made to keep the air in these passages as nearly pure as possible.

It is proposed to warm the floors of the hall slightly in excess of the temperature of the room, say to about 80° or 85°, which would still be below the temperature of the body; and also to have all the exterior walls warmed so that there would be a gentle radiation from all the solid bodies in the room. When we are not losing

* Rand, Perkins & Co., of Philadelphia.

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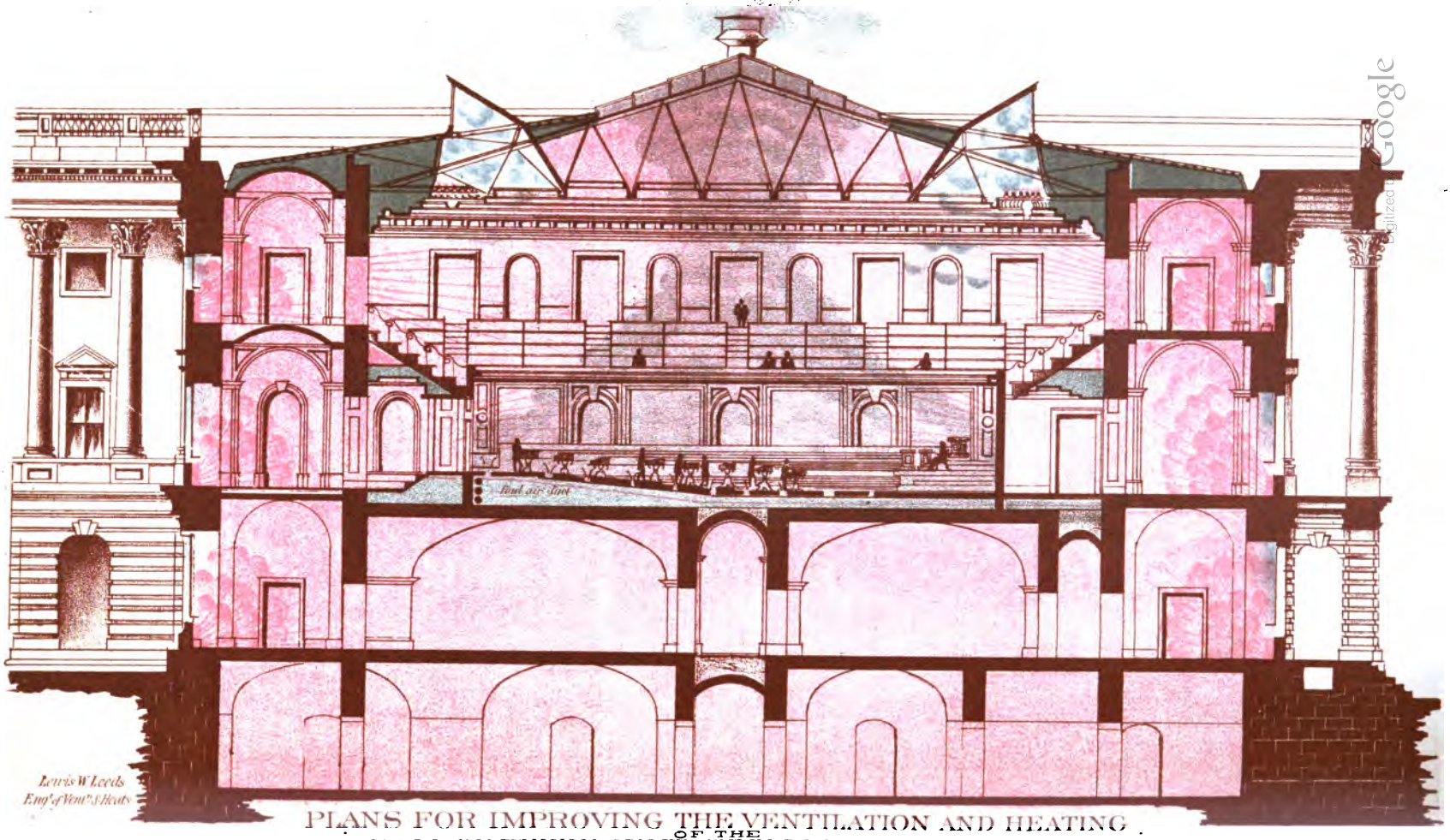

PLANS FOR IMPROVING THE VENTILATION AND HEATING OF THE HALL OF REPRESENTATIVES WASHINGTON D.C.

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heat by conduction, from contact with a cold floor, and are receiving radiant heat from all the surrounding walls, instead of parting with the warmth of our bodies to these walls, we can afford to be surrounded with and have the luxury of fresh, cool, invigorating air for breathing.

As the corridors would be largely warmed by radiation the air in them would be cooler than the indicated temperature; it would, consequently, flow into the hall underneath the air longer contained there.

It is not intended, however, to depend exclusively on the supply of air from the corridors in case the doors should all be intentionally or accidentally closed; there would be an abundant supply of air from portions of the perforated ceiling. In winter arrangements would be made to warm this to the required temperature, but as so considerable a portion of the warmth of the hall would be furnished by direct radiation, it would only be necessary to have this air heated to 50° or 60°; consequently, being slightly heavier, it would easily fall in gentle, well-diffused currents, to take the place of the foul air drawn out both above and below.

Many persons are afraid of a draught of cold air upon their heads, but if the surrounding conditions are right this is just the position to have it strike the body. For instance: I have stood on the hot plates in front of the boilers in the hold of a steamship, with my back towards the hot boilers, and had a perfect torrent of very cold air falling on the head, which felt delightful.

The firemen are constantly subjected to this without injury, but if they go on deck and stand in a draught, or cool off quickly, *away from the radiant heat*, they frequently take severe colds.

One difficulty about having a cold draught upon your head: it is very apt to be *colder* on the feet, but that part is frequently not noticed.

It is also proposed to put in a row of dormer windows, that would let in more sunlight, and perhaps some of the direct rays of the sun, and in summer would be very useful in catching the breeze as it passed and throwing it directly into the hall as you see here (refer to diagram). It is proposed to entirely disconnect the illuminating loft, so as to avoid the possibility of a returning current of foul air as now occurs; also to make an additional plastered ceiling and a confined air-space to prevent the rapid cooling effect of the exposed copper roof.

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It is proposed to dispense with the fans entirely, which I consider about the greatest nuisances in the building, and rely exclusively on heated shafts.

The same amount of heat applied to a well-constructed shaft will probably move a much larger amount of air, at a great deal less cost, and requiring no expensive engineering attendance.

I believe if this plan was carried out it would make a very satisfactory building; perhaps the Hall of Representatives would not be quite equal to a single room, with the walls and floors warmed, and large windows on all four sides for the free admission of air and sunlight, but it would be so much better than many of our public halls, that by comparison it would be considered very good.

Since the completion of these drawings I have shown them to many of our leading architects, and the accompanying certificates, which have been endorsed on the back of those plans, show how universally these principles have been approved by the architectural profession, and they are now making arrangements to have them adopted in most of their new buildings.

NEW YORK, January 28th, 1870.

The plan of combining fresh air supply with direct radiation is, I feel convinced, the arrangement that must ultimately be followed in all large public buildings, and the place of bringing the external air into each room through heaters under the windows is, I believe, the most simple and effective adaptation of the general idea.

CALVERT VAUX.

NEW YORK, January 28th, 1870.

Engineers of ventilation and heating, in my judgment, lay too much stress upon the necessity of supplying fresh air to an apartment by mechanical appliances. The theory of Professor Leeds has for a basis the taking advantage of the natural currents of air; the radiators are placed immediately under the windows where fresh air constantly passes over them, and is warmed to any desired temperature, and the air thus admitted is most agreeable in quality, and free from debilitating effects. The more diffused the inlets for fresh air, the more uniform and agreeable the temperature. The inlets for foul air should also be diffused and placed both at the top and bottom of the room. The system of Professor Leeds is heartily indorsed by me, and seems to have every advantage over any system having "fans" or similar appliances as a basis.

EDWARD H. KENDALL, Architect,
92 Broadway, New York.

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I have examined the plans of Mr. Leeds for the ventilation of the House of Representatives. It is founded upon the system approved by the Commission of the Exposition of Paris as the best, namely, the introduction of fresh air at the top of the chamber and exhausting from the bottom, and I have no doubt that if the air introduced from the top is properly warmed the method proposed by Mr. Leeds will be perfectly successful.

JAMES RENWICK, Architect.

Recent investigation has strongly impressed me in favor of warming the floors in *excess* of the required temperature of the room, say to nearly the temperature of the body, and if this can be done satisfactorily, so that the fresh air required for producing the necessary ventilation may enter cooler than the air longer in the room; thus it may no doubt be found entirely satisfactory to ventilate at all times from the top of the room.

G. P. REANDALL, Architect,
Chicago, Ill.

PITTSBURGH, PA., Feb. 10th, 1870.

Having studied the subject of heating and ventilating public buildings for the last thirty years, and having had the advantage of the personal instruction of Dr. D. B. Reed, of Edinburgh, Scotland, in 1840, both in Edinburgh, and in London at the Houses of Parliament, I most unhesitatingly endorse the views and plans of Lewis W. Leeds, and have introduced the same into the new City Hall of this place. The plan of warming the floors as proposed by Mr. Leeds meets also with my warmest commendation.

J. W. KEER, Architect.

29th January, 1870.

The exit of foul air should be both downward and upward; downward for the quicker escape of the products of respiration, and upward for the escape of products of combustion, both kinds of foulness being carried off directly from the points where they are produced without vitiating the air of the whole chamber. This provided for, and direct radiation being given for warmth, the entry of fresh air is rendered easy. This fresh air may be warmed at entering, or not, at pleasure.

Mr. Leeds' plan seems to us to meet all these conditions and to be based on the soundest principles of ventilation.

RUSSELL STURGIS, JR., & CO.,
87 Broadway.

RICHARD M. HUNT.

January 31st, 1870.

I agree entirely with the above statement.

GEO. B. POST, 6 Hanover Street.

Being requested by Prof. Leeds to express my views on the subject of heating and ventilation, I have no hesitation in saying that I believe the theory that all

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foul air must be drawn from the floor alone, without any provision for its escape from the ceiling to be radically wrong. This course may perhaps be rendered necessary where attempts are made to warm the building by currents of warmed air only. But, in my view, it is a great mistake to attempt to reverse the order of nature and to make the currents of warm air which surround the human body turn downwards. The manner of applying the heat and ventilation shown in these drawings is undoubtedly correct in theory, and if faithfully executed would, I doubt not, fully accomplish the intended purpose.

ARTHUR GILMAN,
98 Trinity Building, New York.

February 17th, 1870.

The views here expressed by D. H. Kendall, Esqr. (Architect), of New York City, so clearly and fully set forth what I have adopted as my practice after many years of experience in the subjects of warming and ventilating of buildings, that I desire only to say, that I most fully concur with that gentleman, in the opinion he has given.

SAMUEL SLOAN, Architect,
154 South Fourth Street, Philadelphia.

The above is endorsed by

CARL PFEIFFER, Architect, New York.

BOSTON, February 25th, 1870.

The idea of warming and ventilation, illustrated herein by Mr. Leeds, seems to me to be the correct one, viz.—a well-distributed supply of warm fresh air combined with direct radiation and a distributed exhaust of the foul air, not merely at the bottom or top, but at both. Without going into detail, the system seems to me to have been adapted to the hall in question with great completeness.

SAMUEL F. THAYER, Architect.

Mr. Leeds' system of ventilation has long been familiar to us, and we have made use of it in our practice with satisfactory results. The application to the Capitol at Washington, as exhibited in these drawings, is ingenious and economical, and satisfies all the conditions of natural ventilation, both in winter and summer, avoiding violent currents of heated air, and distributing an equal temperature. This plan is capable of all those modifications which may be needed in adapting it to new conditions.

WARE & VAN BRUNT,
2 Pemberton Square, Boston.

February 25th, 1870.

We have been giving great attention of late years to the comparative value of warming by hot-air currents and by the combination of direct radiation; and the result of our experience convinces us that it is very essential to perfect comfort in cold weather to have a well-diffused radiating surface in every room, and

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that the general supply of air for ventilation should be cooler than the indicated temperature of the room. If properly constructed, we believe good exhaust shafts, heated at the bottom, are entirely superior to produce the necessary ventilation in all ordinary rooms, and are better than forced ventilation by fans. We believe the plans as proposed herein by Mr. Leeds for the Capitol will give very satisfactory results.

CUMMINGS & SEARS,
10 Studio Building, Boston.

THE TREASURY BUILDING, WASHINGTON.

We have here several drawings to illustrate the condition of the ventilation and warming of the U. S. Treasury buildings.

This is one of the most substantial and expensive executive buildings in the world, having cost some $5,000,000.

No expense has been spared in any part to make it the most perfect, comfortable, and convenient building that the ingenuity of man could devise.

I wish you to make a distinction here between the errors of original design and construction, and the troubles resulting from its shameful abuse, because the former show the deficiencies of correct knowledge in this respect among the best informed architects and builders; but the most shocking condition of the old building and ill health of the occupants, as I found them, result very largely from the shameful abuse of it after its completion, and show us the want of general information in the public, which will prevent the very best arrangement that could possibly be made becoming an intolerable nuisance, as was the result here.

It must be remembered that this whole block has been many years in building and reaching its present size. The plans represent it, as now finished, as a single completed building, but we must examine it in parts, according to the ages in which it was built.

The old front on Fifteenth street has been built probably fifty or seventy-five years—quite long enough, at any rate, to show in its original construction those ample old-fashioned fire-places where hickory wood, and plenty of it, was burned in each room.

And when these were in full blast an examination of the absentee list would show a much smaller proportion of excuses for sickness from foul air diseases than at present, with these fire-places carefully boarded up or walled on top, and all the rooms heated from one large central boiler in the cellar.

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Most of this part of the building has been remodelled, so as to be heated by radiation from hot-water coils in each room, great care having been taken to shut up all crevices to prevent any cold draughts.

The south wing and west wing have been completed much more recently—mostly within ten years. This is the portion of the building which I wish you to examine more carefully.

That cleanly and refined system of murdering human beings which has spread like a devouring pestilence over our whole land, came into general use about the time this building was designed.

I mean that miserable system of warming our rooms by currents of over-heated, debilitating, and ruined air.

At that time I myself was one of its zealous advocates. I had already noticed the universal complaints of the occupants of rooms which were heated by currents of air from the common hot-air furnace, but supposed it resulted from some peculiar effect produced by the overheated iron, and, consequently, went energetically to work to remedy these evils by warming all the air, by bringing it in contact with metal surfaces moderately warmed by circulating hot water.

I persevered many years, inventing and patenting in this country and in Europe new and improved devices for accomplishing this object, fully believing that a building, constantly overflowed with this mild, warm, summer-like air, must be the very perfection of artificial heating.

And yet I was chagrined and mortified that many sensible people, with good independent judgment, would still insist upon it that they felt better, their heads were clearer and brighter, in a room heated by an open fire than in a room heated by my hot-water apparatus.

It was thus forced upon me, little by little, year by year, that there was a very essential difference between the room heated by an open fire and one warmed by currents of heated air.

I was just going to say I *soon* learned, but I *didn't.* I *slowly* learned that all warmed air was unwholesome and debilitating; that it was not the manner of warming, but it was the fact of its being warmed; that the sun itself could not warm it so as not to produce this debilitating effect, as witnessed by the fearful mortality whenever the air in summer reaches nearly the temperature of the body.

In proportion to my convictions of the unwholesomeness of warmed air did I advocate the introduction of direct radiation—first one-quarter, then one-third and one-half, and perhaps some

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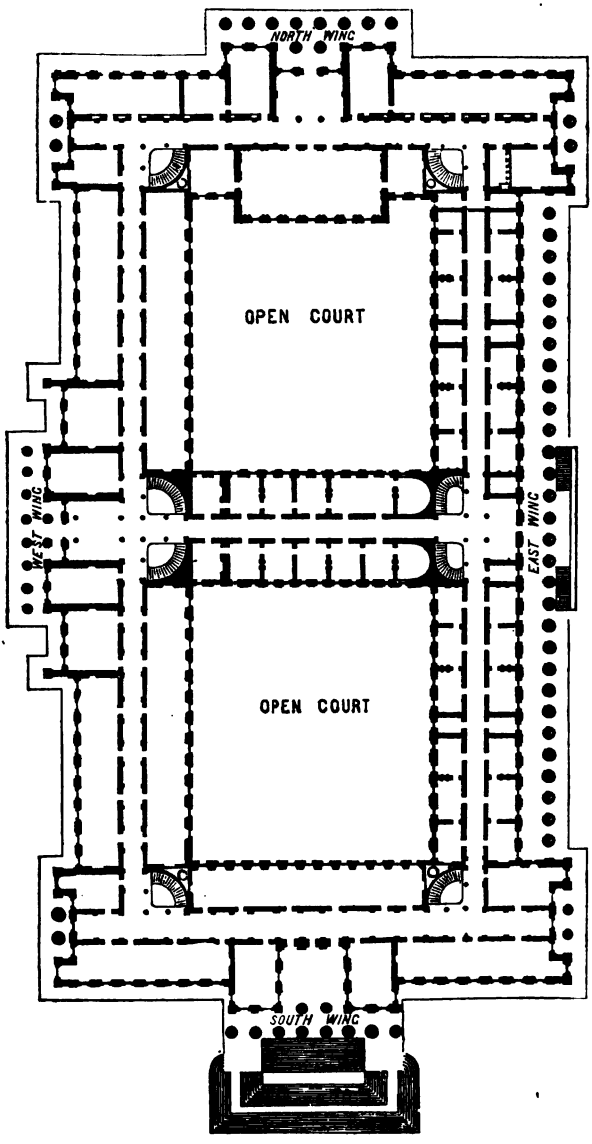
time I may believe in *heating* by radiation entirely. But there is one practical difficulty about this, and that is, where the necessary

Fig. 21.



PLAN OF U. S. TREASURY BUILDING.

air for ventilation is passed through the room, and it is quite cold,

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it is so difficult to avoid unpleasant draughts; it requires very careful diffusion.

There is, consequently, less complaint of such draughts when all that air is warmed, especially as all the occupants are so stupefied they have not much energy left to do anything—not even to find fault.

But now to the examination of our building. You will see by this plan that the building is a parallelogram, 480 feet from north to south, and 260 feet from east to west, with a connecting wing between the two long sides. I would just say that this hollow block form seems to me to be very objectionable, as it completely cuts off the through currents of air, and it is frequently quite stagnant in these inner courts when there is a pleasant breeze on the outside.

You will notice there is a corridor in the centre, with rooms on each side throughout the whole building.

This section (see Fig. 16) is through the west wing.

The hot-water coils for heating the air are arranged along the centre corridor, with the hot-air flues passing up the corridor walls, and the ventilating flues, what there are of them, are in the same walls.

The fresh air is supplied to all these coils by a channel under the corridor floor, and directly underneath this is a large sewer. Now, this was a very good place for the sewer as long as everything was perfectly tight, but I had strong suspicions it was not right, and one day finding the workmen had taken up one of the large flag-stones, I took a light and entered the dark, subterraneous passage, and there I found a dreadful condition of things.

When the cellar and basement were turned into manufactories they had carried the waste steam or blow-off pipes from the extra boilers into the sewer, and the workmen had been careless about repairing the breaks they had made, in consequence of which, and the additional heat from escaping steam, with the badly cracked walls, not only was the foul, poisonous sewer-gas, heated up by the escaping steam, pouring into the fresh-air ducts, but the whole sewer had overflowed and filled this fresh-air duct with the *filthy sewage water*, from 16 to 20 inches deep.

It was not that deep, of course, when I was in there, as it was a dry time, but here are specimens (see Fig. 22) which I pulled off of the scum and slime from water-closets, gutters, etc., which were hanging from the sides and covered the bottom in thick layers.

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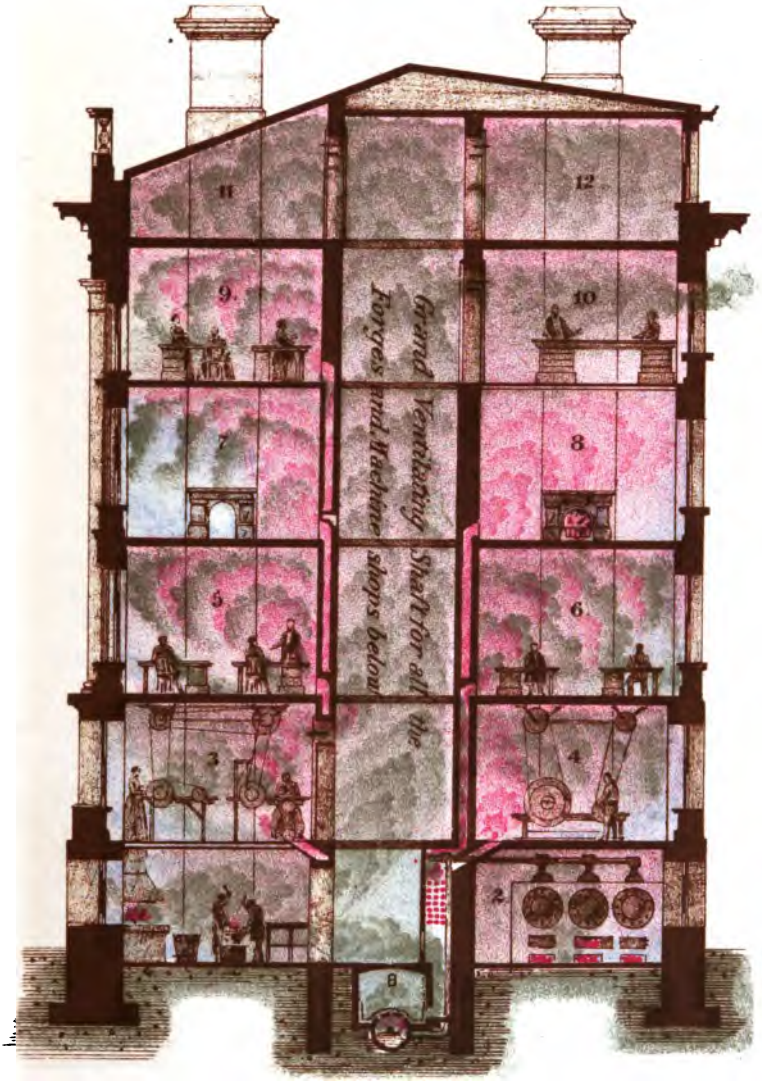

DIAGRAM ILLUSTRATING
DEFECTIVE VENTILATION IN SOUTH WEST WING
U.S.TREASURY BUILDING.

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Here was the worst kind of poisoning of the whole artificial air-supply at its very source.

It may be said this was not the fault of the original design but its subsequent abuse.

Fig. 22.

But I have a very decided objection to long, underground fresh-air channels under any circumstances.

It is possible, of course, to keep them clean and sweet, but in practice they are much more liable to become damp and mouldy, and worse—the receptacle of much trash, often offensive, thrown there by careless or ignorant servants.

If you are not already so sickened that you cannot bear it, I should like to give you a little further description of the actual condition of this ventilating apparatus. You see the heating chambers are arranged on each side of the corridor, and for convenience in getting at the heated coil, there was a door about one foot square opening from the passage-way into the air-chamber under each coil.

In this cellar there were some fourteen steam boilers in various parts, with several heavy forging and blacksmiths' fires, and an innumerable amount of paint shops, etc.; and all this was under a fireproof ceiling, perfectly air-tight; and yet, with all this gas, and smoke, and heat, this cellar was about the best ventilated apartment in the building; and why?—because they opened the doors into these air-chambers and allowed it to flow in, and, mingling with the fresh air! from the sewers, to flow up for the supply of the rooms above.

Now, this is by no means an exaggerated statement of the condition of the air-supply of that magnificent building, with its 2,500 high salaried clerks.

I took a little pains to ascertain the effects of this condition of things upon the employés, by comparing the absentees on account of sickness with those from the Patent Office building for two or three months, which showed an annual loss of some twenty or thirty thousand dollars, a large proportion of which would have

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been saved in dollars and cents, independent of the physical suffering, by continuing the old-fashioned hickory fires.

I found the physicians in the neighborhood had applied to the numerous patients from this building the term "Treasury poison cases."

The opinion prevailed to a considerable extent among the female employés from the warmer States, that the prevalent fevers in that neighborhood arose from the sewers having become so polluted during the war by the proximity of several hospitals.

I intended to have referred to each room separately—which I have numbered for that purpose—but having detained you so long must omit that.

The practical lessons to be taught by this experience are—

1. Never to have long underground fresh-air ducts.

2. Never allow a sewer, soil pipe, foul air-flue, or smoke-flue, to come near the fresh-air supply flue, for fear of some connection being made between them by carelessness or by accident.

3. Never heat a building exclusively by currents of warmed air.

4. Always put the heating flues on the outside walls instead of in the inside walls.

5. Endeavor strenuously to avoid the fresh-air chamber becoming a common receptacle for all the rubbish of a filthy cellar.

You may think such mistakes in construction and such careless management of a large building very seldom occurs, and therefore is entirely an exceptional case.

It is not an exceptional case. How many hotels can you go to, but what the first thing that meets you on entering is the mouldy, stale smell, probably first of the smoking-room, then of the bar-room, next some underground laundry, then the oily smell and heat of the engine, and these interspersed with the odors of water-closets, kitchen, cockroaches, etc., etc., to the end of the chapter.

Is there one of our large new printing establishments but what is saturated from top to bottom with the smells and heat of the engine and press in the basement? and the halls of the establishment are the actual ventilators of the boilers and engine house, just as these halls of the Treasury are the great ventilators for that cellar and basement.

No, my friends, you will find this is only too true an illustration of a very large number of our public and many private buildings, and it is time we acknowledged its truthfulness and set ourselves to work in earnest to endeavor to remedy these defects.

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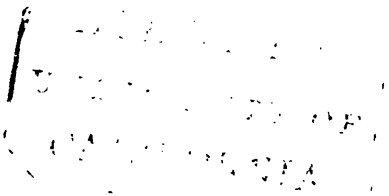

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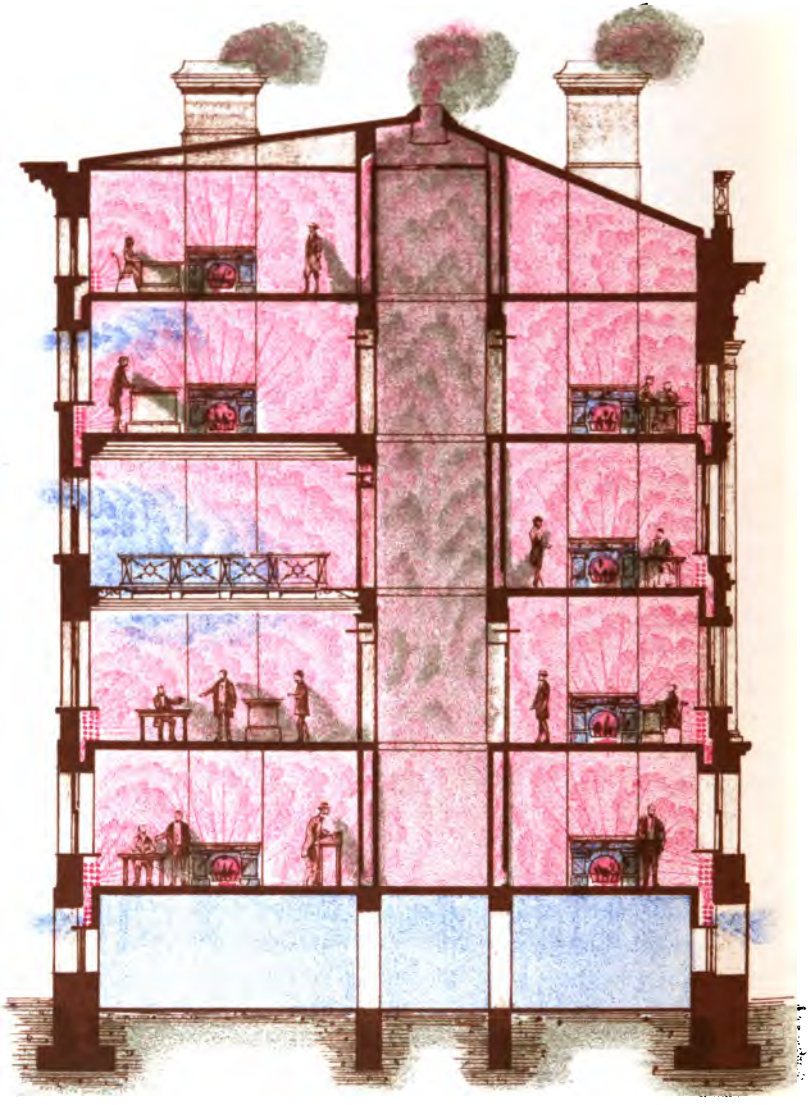

DIAGRAM ILLUSTRATING
IMPROVEMENTS IN THE PLANS FOR THE VENTILATION
OF THE NORTH WING U.S. TREASURY BUILDING.

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Now let us glance for a moment at this section of the north wing of the Treasury. Here we have a combination of heating by direct radiation from hot-water pipes, exposed in each room under the windows, and a well-diffused supply of fresh air partially warmed to prevent cold draughts.

There are no underground fresh air ducts, but all the air is supplied from windows above ground.

The heating surface as well as the fresh air supply is all on the outside of the building, and the ventilation is from the centre because the natural currents are from the outsides towards the centre.

There is a good-sized flue for the ventilation of the boiler room, and a separate one two feet square for the water-closets.

The whole building is warmed by circulating hot water well distributed on the outer sides of the rooms, and although not entirely perfect in all its details, as much of the materials for the building had been prepared before I was called upon by A. B. Mullett, the newly-appointed Supervising Architect, to give the plans for ventilation and warming, yet it is so superior in simplicity and efficiency to the other portions of the building, as to give us much encouragement that we are progressing rapidly in the right direction.

The force of the current through the hot-air flues, as well as that through the ventilating flues, is so rapid as to prove completely the entire uselessness of the fan for forcing a current into any such building with well-constructed flues.

LEDGER BUILDING.

[View on the screen.]

This is a building I feel a great delicacy in saying anything about.

It is one of the most conspicuous, costly, and elegant buildings in the city. I have a very high opinion of the intelligence and liberality of the proprietors, and I believe they have not intended to spare any pains in making the building as comfortable as money and the ingenuity of man could devise.

But they have almost entirely forgotten the supply of pure air.

Go on to that observatory and look over the roof, and you will be puzzled to find one foot of opening for the escape of foul air. The architect has not allowed that beautiful sky-line to be marred by anything so nonsensical, as too many of them consider ventilators to be.

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They may say they have plenty of windows, but that is not the thing. We all know we can get plenty of fresh air by going out of doors, and opening windows is only equivalent to the same thing.

The engine room, boilers, and printing rooms are in the basement, and I am inclined to think will cause much discomfort by the unpleasant smells and heat arising through the building.

Now, it is one of the easiest things in the world to make that waste heat, at the very bottom of the building, instead of spreading over the building as a nuisance, do the work of ventilating the whole establishment splendidly, and I should be perfectly rejoiced to see the proprietors of the "Ledger" ventilate their building in a thoroughly scientific and correct manner.

Do you recognize that statue in front as that of the great Franklin—the father of ventilation—don't you think it must be a sore grief to his spirit (if spirits are cognizant of things going on in this world) to see his image thus fastened up to public gaze in front of such a badly-ventilated building as this?

Now, this is merely a fair specimen of all the great newspaper establishments in the country. I have been in a great many, and they are universally *heated* by direct radiation from exposed steam pipes, and not the first foot of ventilation provided either for supplying fresh air or carrying off the foul.

HOSPITALS AND ASYLUMS.

Perhaps in no other class of buildings has there been so much attention given to the subject of ventilation as in our Hospitals and Asylums.

In many of these buildings a good degree of satisfaction has been attained in this respect. There are many deficiencies, however, in these, especially with the very expensive artificial arrangements.

Much valuable information was gained during our late war, although purchased at an enormous expense, in regard to the construction, ventilation, and management of hospitals, and no point was more fully settled than the paramount importance of an abundance of pure air and sunlight for the rapid restoration of those confined in them.

This point is now considered of such great importance that it is

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scarcely considered admissible to build a double-roomed building; that is, a building with a central hall and rooms on each side.

Of course, in some cases it becomes necessary, when very strict economy is absolutely required in the first construction.

This is a most valuable point, too. It is now argued—and with a good deal of reason—that if by having only a single room with sunlight and pure air poured in on all sides, the patient recovers in half the time, which he will do, it is better to pay twice the price for such a building, than to get double the number of rooms by cross partitions, which obstruct the free flow of air. This is a great fundamental principle which ought carefully to be borne in mind in the construction of all buildings, dwellings as well as hospitals.

As before remarked, I think we really have made considerable progress in the ventilation and warming of this class of buildings, although in a very elaborately prepared work on hospital construction, lately published by Dr. Smith and others, after making a very critical examination of most of the costly engineering schemes for artificial ventilation and warming, they condemn them in most emphatic terms, and by comparing the rate of mortality in these with buildings heated and ventilated by the old-fashioned fire places, come to the conclusion that the problem of properly ventilating and warming our large public buildings is yet an unsolved one.

I think they have some good reasons for coming to this conclusion.

For instance, if we take the new Marine Hospital just finished in this city (Philadelphia), a fine view of which we will now throw on the screen, and a plan of the heating and ventilating arrangement I will explain by a diagram on the blackboard.

Here is the boiler-house situated a long distance from the building, and in or near it there is to be a fan for forcing all the air for the supply of the whole building through an underground air-duct to the farthest extremes of the whole building.

In the cellar are the coils of steam pipes for warming the air before it is thrown into the building, and from each room, even to the third story, I believe, are another set of flues for returning the foul air, which it is proposed to drive clear back again and out through a space around the engine chimney. And my impression is that this space for the exit of the foul air is much smaller than the aggregate of the flues entering it.

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Here again are the foul-air flue and fresh-air duct running a long distance together, with nothing but a thin brick wall between them, and, like the Treasury sewer and fresh-air duct, will likely be perforated in half a dozen places before the building is long in use.

Now it does seem to me to be the very height of engineering nonsense to go so many hundred feet down towards the banks of a sluggish fresh-water stream to get fresh air, when purer and better air is pressing upon every window with a force of fifteen pounds to every square inch; and can you imagine why it should be attempted to force that foul and warm air down from the two or three stories of this whole building and clear back to the engine house, when any ordinary flue would allow it to escape quite as fast as the fan would drive it in, and by the simple application in those flues of a small amount of the heat required to drive the fan, would cause a strong draught at all times, summer or winter, whether the fan was forcing in the air or not?

Here we have those objectionable features of long underground fresh-air ducts, and in direct proximity to the foul-air shaft, with all the air overheated, and no direct radiation, and attempting to force or coax all the foul air from the various portions of the building so great a distance to one exhaust shaft.*

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* Since writing the above, and in the early part of 1871, I visited this hospital to examine the practical working of the ventilation and warming. The physician referred me to the engineer; he informed me the fan was very seldom run except on special occasions, when committees were visiting the institution. After some difficulty we succeeded in getting into the foul-air chamber around the engine chimney. We found there a strong exit current. But on examining the ventilation in the various wards we found most of the ventilators closed; but there appeared to be an entire absence of any current either in the few that were open, or in the large number we opened (15 or 20 probably) in various parts of the building, both top and bottom.

I thought it was a little singular there should be no current, either out or in. There was certainly considerable air passing out the exhaust chimney. The engineer thought it quite probable that there might be several openings between the fresh-air and the foul-air channels, which the workmen might have made and omitted to close up tightly. I noticed also that in nearly all the heating chambers the door was open for the purpose of getting the fresh-air supply from the cellar, instead of drawing it from the fan room.

Thus, the whole of this elaborate and expensive arrangement, like most similar ones, when carefully examined was found to be almost entirely inoperative; and with all that fine show of ventilators, so liberally distributed top and bottom, the poor patients were not getting a breath of pure air which could be credited thereto.

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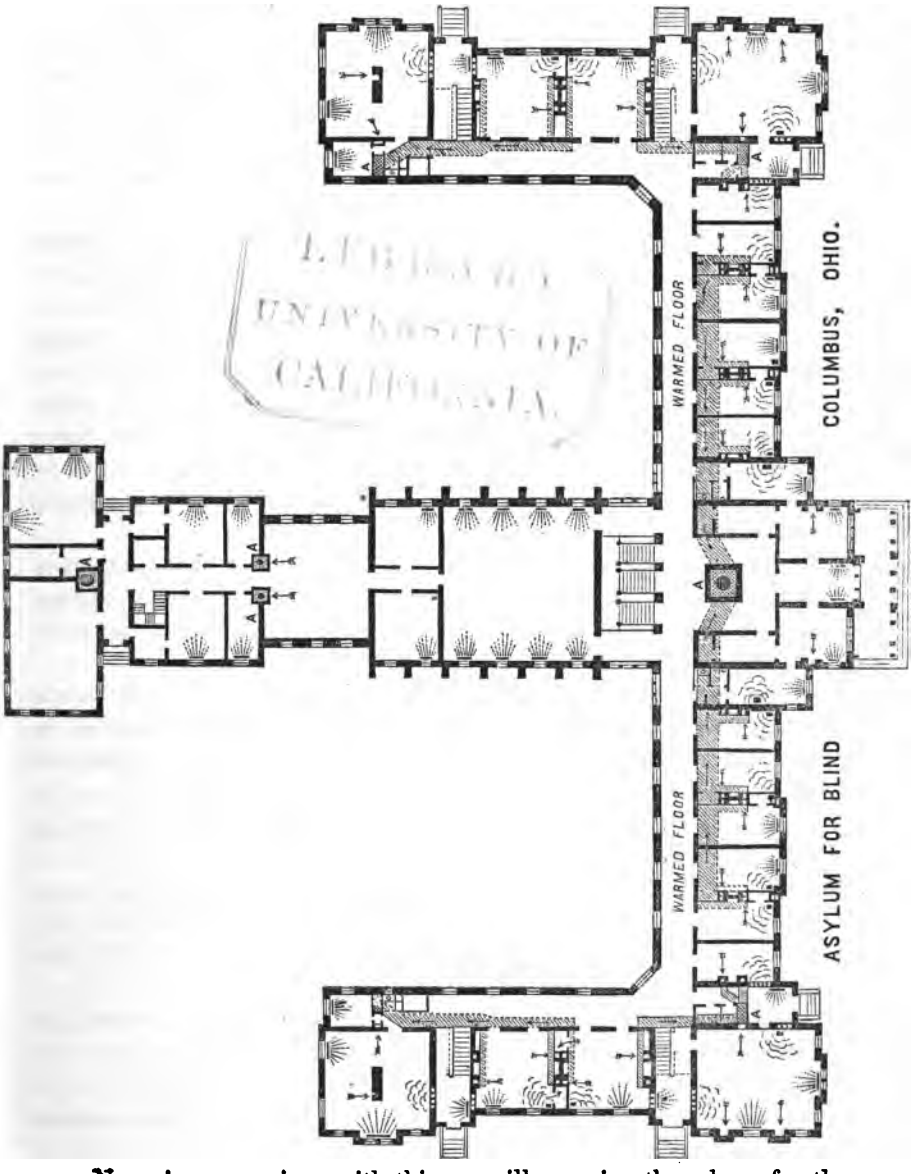
Fig. 23.



Now, in comparison with this we will examine the plans for the ventilation and warming of the Asylum for the Blind to be erected at Columbus, Ohio.

(I have substituted these plans in the publication of these

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lectures in place of some others used at the lectures, as they contain in a more condensed form the ideas designed to be expressed. The building is not completed, and the building committee may not conclude to execute these plans, wholly or in part, but they were prepared at their request merely as giving my ideas, were submitted and paid for, and I have nothing further to do with the execution of the work; but I use them to express general principles applicable to all similar buildings.)

This building is to have a forced ventilation by means of heated shafts A, A; but notice, if you please, the position of these shafts and see how they are distributed in the various parts of the building.

There have been many attempts of late years to ventilate large and irregular buildings by one grand central shaft placed at considerable distance from the buildings. Many failures and much disappointment have resulted from such arrangements, and many persons began to conclude that there was no dependence to be placed upon heated shafts for the thorough ventilation of a group of buildings.

A heated shaft creates an exact definite force just in proportion to the excess of heat of the air it contains over that of the external atmosphere, and its power can be calculated with just as much accuracy as that of the fan driven by the steam-engine.

For economical working it is desirable that the currents should move slower and with less pressure than is frequently exerted by the fan. Consequently it requires much care in the adjustment of the inlet and outlet flues. Much trouble frequently occurs for want of care in making arrangements to work *with* the natural movements of the air, and not against them.

The additional pressure of the atmosphere during a high wind amounts to many tons, often hundreds of tons, on the windward side of a large building, while there is a partial vacuum created on the opposite side.

The supply for each room and the exhaust should be arranged independently for each exposed side so as to work in harmony with these natural forces, and then there is no difficulty whatever in its perfect working at all times. But with a single fan in a central position no such modification can be made; it must be a uniform pressure on all parts of the building, that is, at equal distance from the central force, consequently the rooms most favorably situated will receive an over-due share, while in other portions of the build-

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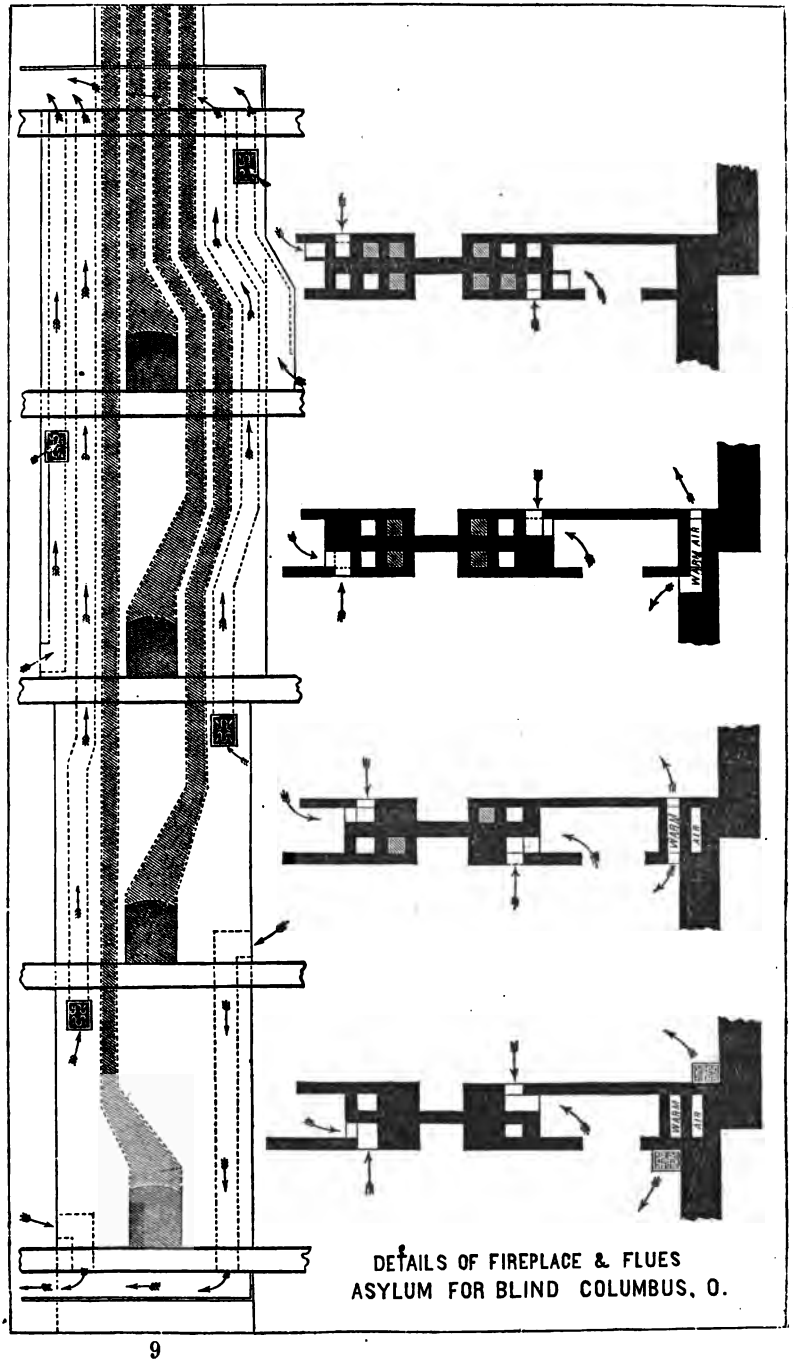
Fig. 24.



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ing the force of the fan may be just equal to the external pressure so as to produce almost perfect stagnation.

It is always desirable to have as few horizontal air-pipes as possible, either for the supply of fresh air or discharge of foul, but where it is intended to apply heat to the exhaust shafts for the purpose of forcing the ventilation, it is more convenient to have fewer of them, and consequently somewhat concentrated.

I endeavor to avoid drawing the foul air downwards as much as possible, because as it leaves the room when quite warm there is danger at times of a regurgitation, but sometimes the construction of the building or arrangement of flues makes it more convenient to do so. Then care should be taken to make as few openings as possible into the same duct. In this case we take the coldest air—that from the floor of first and second story.

For the heating of this building I proposed about one-half of the steam heated surface to be exposed for direct radiation in many of the rooms and passages, the radiators to be placed under the windows so as to get the fresh air supply conveniently by raising the window more or less as desired.

The remaining half to be placed in the cellar for partially warming a supply of air at all times whether the windows were opened or closed.

In addition to this the architect has provided for fire-places in nearly every room. These will answer an excellent purpose for ventilation even when not used for open fires.

But in addition to these fire-places each room is provided with a flue connected with one of the heated shafts, with opening top and bottom (see detail plan) to insure a forced circulation at all times, especially in spring and autumn, when it is too cold to have the windows raised, and yet not cold enough to have fire; forced ventilation is then very necessary.

It was proposed to warm the whole of the corridor floors, which would give an even gentle warmth to the halls and stairways without overheating the air.

By thus warming the floors the heat is retained where most wanted—at the bottom; but when hot air is thrown into such halls or corridors it escapes at once to the ceiling, and frequently up the open stairs to the top of the building, without effecting much good.

By having the floors warmed in this manner without any projections or obstructions to the free passage of the blind inmates, these passages would make good exercising halls in stormy weather, as

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they could have a free circulation of pure air by opening the windows, and still retain a well-distributed heat supply at the point where most needed.

The kitchen and bakery have each a large ventilating flue (A) surrounding the smoke flue from each of these fires. Also for the engine room and laundry there is a large shaft around the boiler chimney.

A building thus warmed has its source of heat in each room, entirely uninfluenced by the shifting course and varying strength of external currents; and so large a proportion being derived from direct radiation, the rooms may be filled with air cooler than the indicated temperature.

If the windows are all closed, there is a constant supply and exhaust for each room taken directly from the external atmosphere without passing through any horizontal air-ducts (which are always liable to become dirty and foul); or, by opening the windows, the fresh air flows over the warmed pipes, and passing in its natural course to the halls or the exhaust shaft, merely adds to the more abundant ventilation, without danger of disturbing the supply of heat.

It may be said, of course, that this building is not completed, and if these plans were executed, there might be as many failures as in the Philadelphia Hospital or many of those buildings now completed, the arrangements for the ventilation and warming of which were anticipated to be so perfect.

But the leading features here illustrated have been executed in a large number of instances within the last few years, and have given very general satisfaction. And to any one who will take the trouble to "think about it" carefully, the correctness of these principles will be perfectly evident.

CHURCHES.

Here we have on the screen a copy of a photograph of a very beautiful church near the Falls of Schuylkill.

Can you discover anything breaking that beautiful sky line that would lead you to suppose its designers or builders had the slightest conception that the moving machines which go out and in there were breathing animals,—that fresh air was ten times more important to them than food?

I did not select this because there was any peculiarity about it

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in regard to the ventilation; it is simply an illustration of all modern churches.

I say modern churches; I don't mean that they are modern designs. It seems as though we have no ideas of our own for planning such buildings to suit the present needs and habits of our

Fig. 25.

FASHIONABLE CHURCH WITHOUT A PARTICLE OF VENTILATION.

people, but must copy from those old buildings made several centuries ago, even before chimneys were invented; so that, if we want a chimney, the architect says very emphatically, "You can't have it; it does not belong to the style." But our modern hot-house plants cannot go to church for fear of taking cold unless the room is heated nearly as hot as an oven; so they have to resort to some kind of deception, and frequently attempt to conceal a smoke flue in one of the ornamental finials. But their cheating is soon exposed, and the reputation of the architect as well as the beautiful ornamental work is blackened by the smoke from the burning fires below.

And as to allowing the whole design of the building to be utterly spoiled by having a great ventilator placed on top of it, such a thing could not be thought of for one moment.

Now, I wish there was some way of finding an American with ingenuity enough and sufficient independence to design an American building; and as we must have, as every one knows, several fires in such large buildings as most of our churches, be honest

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about it, and tell the truth by showing one or more good, substantial chimneys, and in addition to that to have an ample ventilator or outlet for the foul air. I think such a man would soon earn a very enviable reputation among our practical, common-sense people.

We must admit, however, that there is also something to be learned by the rest of us—the architects are not entirely to blame—as, for instance, we find some mistakes even in a new meeting-house, built by Friends at Germantown; there they were not troubled by architectural rules. One of the special reasons for abandoning the old building and erecting a new one was to accommodate the new idea that had just begun to dawn upon the minds of the people, that it was necessary to have ventilation, even in a meeting-house.

Each member of the committee, therefore, as is usual in such cases, I suppose, felt it his special duty to devise and urge a new and valuable improvement in ventilating meeting-houses.

Although each one might be entirely different from any of the others, yet they would be urged with no less earnestness and confidence, owing to their being quite new (all plans for artificial ventilation, except the open chimney, are necessarily new).

Well, the house was ventilated, and quite a liberal allowance of ventilators were displayed all around the sides, top, and bottom, and all led into a conductor behind the cornice which was carried to the chimney; but it was a real, honest chimney, however.

(It was suggested to me that the size of this flue behind the cornice, for receiving the air from all the other flues, was only half of one square foot on each side.)

Now, this committee thought they were going to have one of the best ventilated buildings in the world, but just imagine their disappointment for the first time it was occupied on a cold day, to find those persons near the ventilators shivering, and putting on their overcoats to protect themselves against the cold draughts from the open ventilators.

They had made the very common mistake of locating the ventilating flues in the cold outside wall, and in frosty weather the air in those flues being colder than the air in the main part of the building, it of course would fall down and pour out into the room.

They also followed the inclination of all heater men, and, probably, the advice of the one that put these heating registers in the centre of the room, instead of around the outsides; consequently,

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those in the centre would be suffering with heat and foul air, while the ones on the outside were complaining of cold.

Our whole practice of ventilating and warming such buildings is about as incorrect and unscientific as could be well imagined.

To have a large building closed up several days of the week, until the walls and floors get thoroughly cold, and then a few hours before the assembling of the people to build a fire in an old rusty furnace, throwing in a stream of highly heated air until it gets warmed down a little below the heads but leaving the floor and feet cold, so that the occupants must breathe warm, debilitating air, while the walls, floors, and furniture are rapidly absorbing the animal heat from the body, are conditions very unfavorable for sound, active, mental exercise.

They are stupefying.

And, again, to place the heaters in the centre of the building instead of on the outside is erroneous.

Let us endeavor to examine by this diagram on the blackboard (see lithograph, No. 18) the movements of the air in such a room.

I say let us examine these currents; we cannot see them, of course, but if we would only think a little every person here must *know* almost precisely the movements of the air in such a room, under certain well-known conditions.

We all know, for instance, that each human body is 98° at all times. If the blood falls a very few degrees below that life is extinguished; so do we know that the air from a hot-air furnace very commonly rushes into a room at temperatures ranging from 200° to 300°, and by watching the particles of dust, etc., we see that this air rises immediately to the ceiling and spreads out there.

We also know there is a strong descending current of cold air under windows and along cold outside walls; this air sweeps back along the floor, and again rises near the centre of the room.

Now, suppose there are twenty-four persons sitting side by side. You see at commencement the first one would have quite pure air to breathe, the second not so pure, the third one would have to breathe soiled air—the air that had come from the lungs of the first and second, and that which had swept over their bodies and absorbed the exhalations from them. The fourth one would have to breathe foul air, the fifth very foul, and the sixth, well,—I hardly know what to say,—I want you to stay with me until the close of the lecture, and I don't think it would be best to attempt to describe

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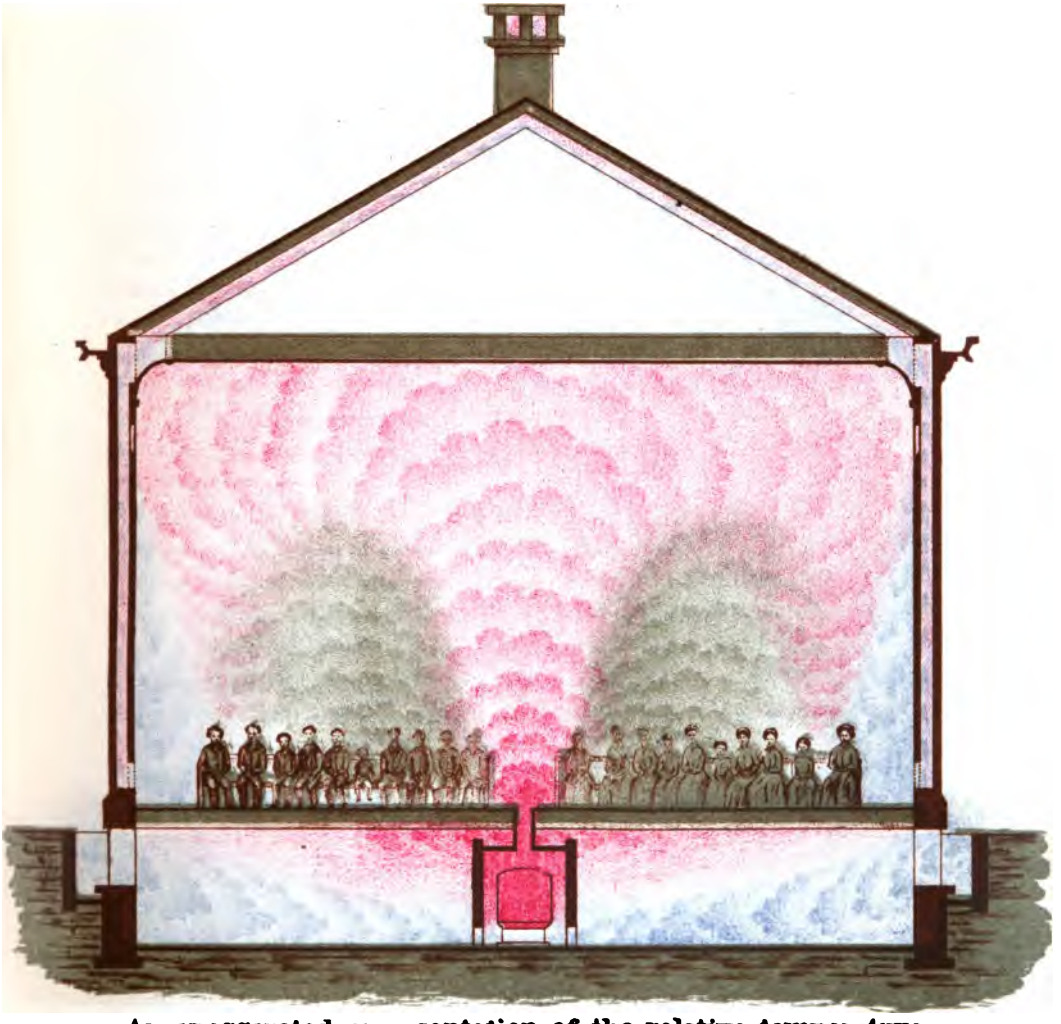
Fig. 10.



An exaggerated representation of the relative temperature and movements of pure and fouled air in a well filled room, heated by air from a furnace opening into the centre of the room.

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what those poor victims at the other end of the seat must have to breathe.

Now, we all know this is just the condition of our large halls, when they are well filled. We also know how we suffer with heat and oppression when we are in the centre of the room, and yet how chilly it is near the windows.

Or in summer we have noticed how warm and foul it was, even in the open air, if we get near the centre of a large number of people; or in crossing the river on a steamboat, when it is quite crowded, I have noticed, by standing four or five back from the front, it would be quite oppressive, even with a brisk breeze blowing in front.

Notwithstanding we are all aware of these things, yet here is a committee of as intelligent men as you will commonly find associated together, and yet these men, like most others, when it comes to ventilating such a building, seem to take leave of their ordinary good judgment, and allow such awkward, incorrect, and unscientific arrangements as these to be made, and will allow themselves and their families to be annoyed and poisoned, year after year, rather than to make a determined effort to remedy it.

The very common fault of taking the air for the furnace directly from the cellar, without any fresh air box, is practised here. If the window is opened to let in fresh air, this cools the whole cellar, and consequently the floor of the room above, instead of which the cellar ought to be shut tight and heated hot, so as to warm the floor above, and a separate box should be provided for the supply of fresh air.

As an improvement upon this I have introduced a section of

ST. ANN'S CHURCH, BROOKLYN,

showing the manner of ventilating and warming that building.

(These plans were not used in the lectures, as they have been made since.)

The whole building is heated by low-pressure steam, and, as will be seen by reference to the accompanying lithograph, all the heating arrangements are placed on the sides under the windows, and in this case the fresh air, for the main audience room, is admitted over the head of the basement windows, and, passing over the steam pipes, enters the room well diffused along the whole side.

Those in the main audience room are screened by a cast-iron

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wainscoting, perforated at the top for the outlet of the fresh air. This warms the whole side of the room near the floor, as well as gives an abundance of fresh air. By perforations in the ceiling of the galleries, the warmed air passes through the upper angle of the galleries and behind the wainscoting, where there are three additional pipes; and this warmed air rises by the upper windows and completely cuts off those cold descending currents from the windows.

By a series of carefully tried experiments, with ten thermometers hung at equal intervals across the whole room, there was not three degrees difference; those close by the heating apparatus, on the outside, were about two degrees the highest, but this would be compensated for by the greater loss of heat by radiation from persons sitting near the cooler windows, so that it might be considered almost exactly equal.

By furring down the basement ceiling five inches, a space was secured for the escape of the foul air from the ceiling of the basement, and from the floor of the main audience room from each pew.

These foul-air ducts are carried to the towers in front, in which are steam coils for insuring a greater draught.

These exhaust-shafts are five feet square each, giving an area of fifty square feet in the two.

I was quite desirous of having the heating pipes placed immediately under the basement floor, for the purpose of warming the floor of that room, but owing to the difficulty of sinking the boilers sufficiently to return the condensed water, this was not done, but the pipes were placed under the windows on the outsides, which answers a very good purpose, but not quite equal to having the floors warmed.

It will be noticed the process of warming the room is entirely different from the previously described meeting-house.

In that case all the warmth was derived from the introduction of currents of warmed air. These raised directly to the ceiling and spreading out horizontally, crowded the colder air down, and so on until the whole room was filled with warmed air. In rooms thus warmed it is often excessively hot at the top and in the galleries before the warmth begins to be felt on the floor; but with this it is quite different—the heating surface being directly in the room itself, the heating commences at the bottom, and it may be quite hot there before it is warmed at the top.

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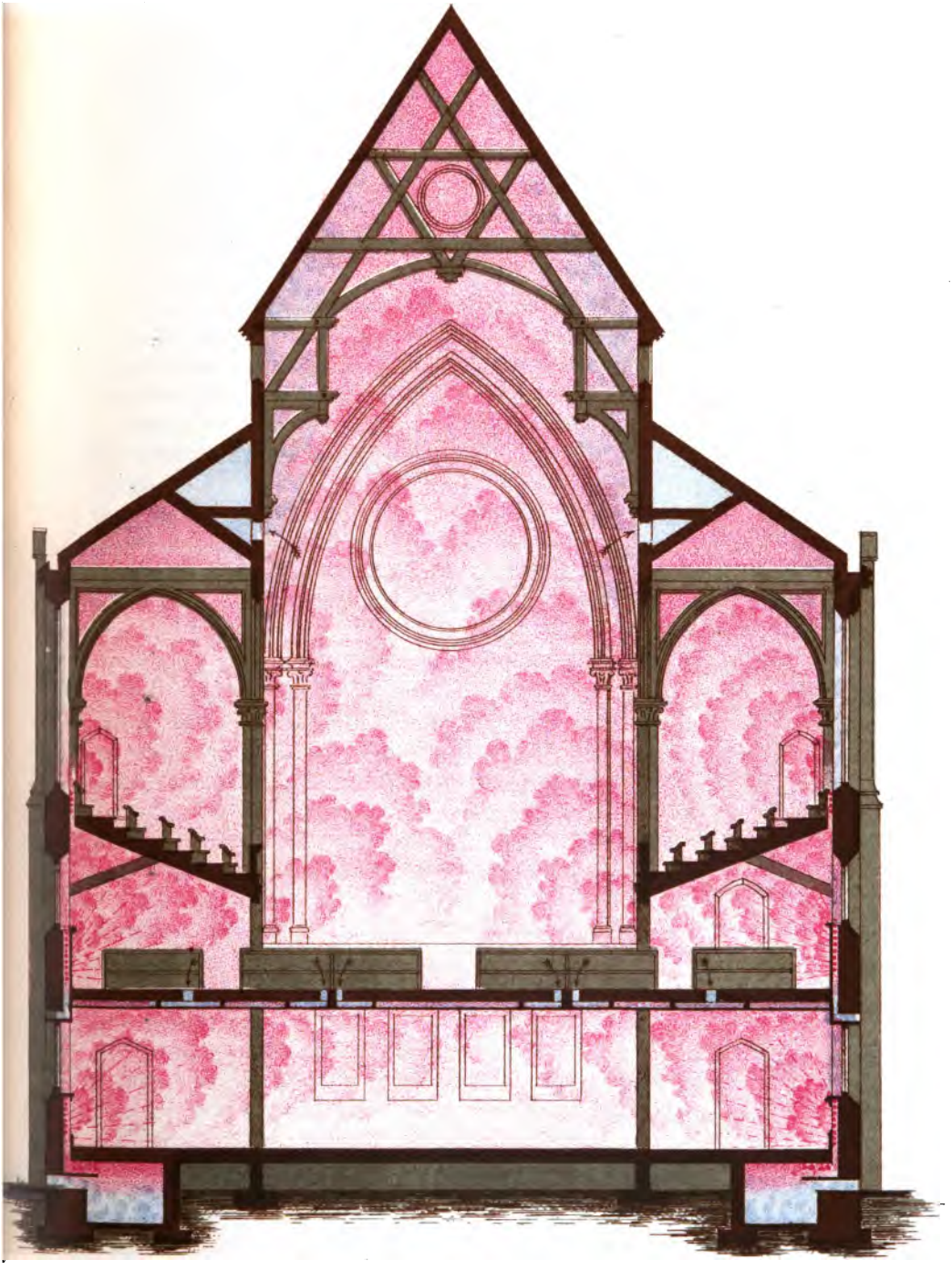

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The first winter the building was used there was complaint of cold draughts in the centre of the main audience-room, and on careful examination I found it was only in commencing the heating as the cool air from above descended to take the place of the hotter.

For instance, when the whole room was 35° on turning on the steam, the effect was felt at once under the galleries, so that it was soon comfortable there; but, of course, as the warm air rose the cold air tumbled down to take its place, which gave the thorough agitation and revolving motion to the whole mass, just as putting fire under a pot of water sets the whole to revolving.

But when the whole air in the room gets heated to 65° all inconvenience from these unpleasant draughts disappears.

As superior as these arrangements are to the ordinary methods of warming such buildings, they do not obviate the necessity of commencing the fires a few hours before the gathering of the congregation.

As the immense height of this building, with its three rows of windows on each side, and large, exposed roof, cools the air so rapidly, it is impossible to heat this great mass without the expenditure of a large amount of coal; there is therefore a strong temptation to economize as much as possible in this particular, at times, perhaps, to the inconvenience of the audience.

But I believe under no condition whatever is there any complaint of foulness or stagnation of the air, either in the main audience-room or in the basement; and when care is taken to commence in time to have the whole of the air warmed to 65° or 68°, the whole building is as perfectly comfortable and satisfactory, both for warmth and ventilation, as could well be desired, even when crowded.

There is a very simple way of making many buildings much more comfortable than they are usually; that is, by heating them to 80° or 90°, so as to warm the walls and floors and all solid objects in the room to that temperature before they are occupied, and then allow the fires to go almost out, and supply the air cool and fresh when the congregation assembles.

But we shall have to wait for a new generation of care-takers or sextons before this can be hoped for.

I know of no more entirely hopeless undertaking than to attempt to convince the sexton of a church of the propriety of heating up his building so long beforehand, and then to let the fires slacken on the gathering of the congregation.

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They are as thoroughly impervious to all argument on the subject as any class of men in the world, except, perhaps, sleeping-car attendants.

We have here the plans (only part have been introduced here) for the improvement of the ventilation and warming at

WESTTOWN BOARDING-SCHOOL.

Fig. 26.

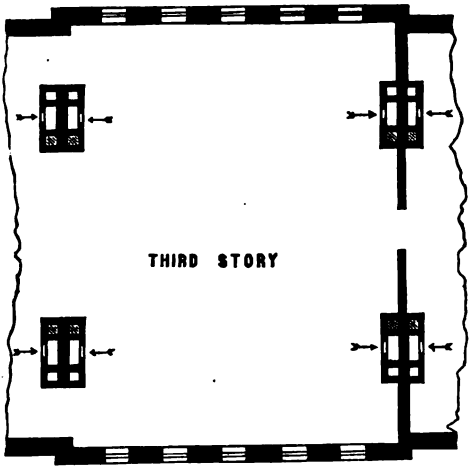


Fig. 27.

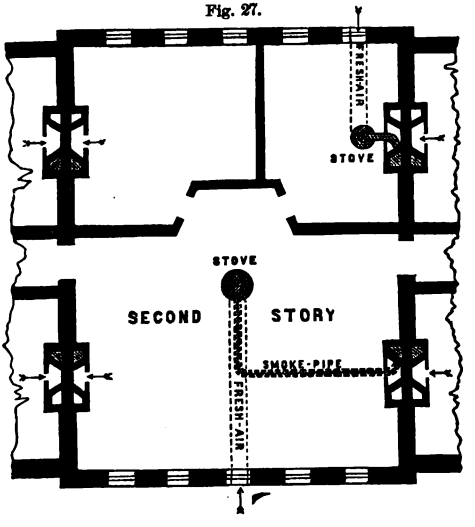
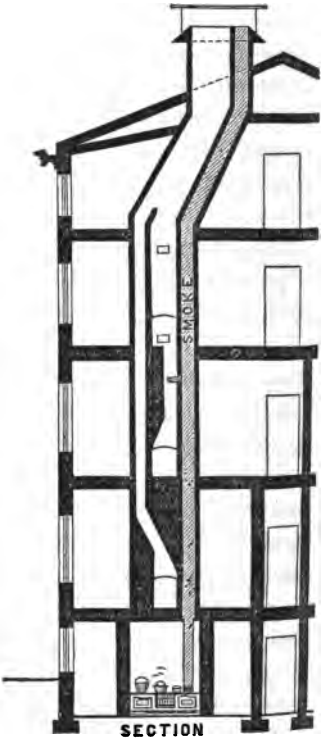


Fig. 28.



PLAN AND SECTION SHOWING MODIFICATION OF FLUES AT WESTTOWN.

I wish to call your attention particularly to the manner of utilizing the old fire place flues.

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Open hickory fires were used when the building was first constructed, but these good old ways of our forefathers were abandoned for those modern nuisances, hot-air furnaces, and the old fireplaces were walled up with much care.

Some time after a fever breaking out, and becoming so alarming, the school was closed and children sent home, and the building examined with a view to the improvement of its ventilation.

We thought it desirable to utilize these old flues for ventilation, but in many of them it was necessary to have a stove-pipe from some of the upper rooms.

Now, it is not good to open a ventilator in the same flue that is used for smoke, because by letting a rush of cooler air into a smoke flue the draught of the fire is very much interfered with, and the smoke from the fire may at times be blown out or the soot might fall down and soil the carpet.

Should such a thing occur one day out of the 365, it would be condemned very likely as a ventilator and closed up.

But to avoid these objections you see we hit upon the happy expedient of using the basement flue exclusively for a smoke-flue, and turned all the smoke-pipes into it, thus liberating all the others which are used for ventilation.

It may be asked if it is a good plan to turn several smoke-pipes into the same flue. Within certain limits, each additional stove-pipe would increase the heat of the flue.

These flues being 13 inches square would have an area of 169 square inches; this would be equal to 6 or 7 ordinary stove-pipes, as it takes but a small amount of air for an anthracite coal fire in a stove.

The case is quite different, however, with an open fire or a wood stove, which requires a larger flue. Several fireplaces opening into one flue in this manner would be likely to interfere with each other.

For open fires it is better to have separate flues for each, to avoid the gas and smoke from one being blown out of the others by sudden gusts of wind.

This building is a good illustration of how great changes in the sanitary conditions with which we are surrounded may take place, but so gradually as to be almost unnoticed by us.

Some of the older Friends, who remembered with pleasure the happy days of their childhood spent at that school, remonstrated

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quite energetically against the new-fashioned ideas about *ventilation*. It was good enough for them, as they were always very healthy there, and they did not see why it was not sufficient for their grandchildren.

They did not approve of spending so much money on these new things, but they entirely overlooked the important fact, that with the original open fires there was more ventilation in one room than was now provided in ten rooms for their grandchildren.

And again, these rooms were now supplied with air for breathing which frequently came into the rooms at 200° or 300° (most debilitating stuff), while the air they used to breathe was seldom over 40° or 50°, and the warmth they received was from the pure rays of the open fires.

Another great change had taken place by the overshadowing of the building by the elegant trees surrounding them.

In its earlier days when first built upon those beautiful hills, the bright golden rays of sunshine bathed and permeated the whole house, thoroughly disinfecting and purifying it from cellar to garret, and no doubt this influence was strikingly reproduced in the sparkling eyes and glowing radiation from the cheeks of all the inmates.

How changed now.

With the sun several hours high, there was that dark, gloomy feeling that made me feel sad; and as I looked at the few puny bleached flowers in some of the windows which were struggling for existence, just kept alive by the few stray sunbeams that now and then stole through the dense foliage, I determined to make one vigorous appeal for a little more sunshine.

But oh! what a stir the dear Friends made when it was proposed to cut down those beautiful lindens that their fathers had planted and had been nursed with such care, and worse yet when those magnificent firs were marked out as more than useless incumbrances of the ground.

A few of the lower limbs were trimmed out, but not one-quarter enough.

I was very much pleased with the striking contrast to this sunless, gloomy picture on visiting soon after the Juvenile Asylum, on Washington Heights, New York.

On approaching the building, although in winter, we noticed all the windows of the dormitories were open, and I think there is

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not a single leaf of a tree allowed to cast its shadow on any part of the entire building.

It was very pleasing to learn that there had been but 2 deaths in 5 years in a family of 600 children. Many of these are picked up from the gutters and streets of New York—mostly from that tenement-house population that furnish so large a portion of early deaths.

There are a few hours in the middle of the hottest days in summer when the shade of surrounding trees may be advantageous, but there are many more hours in the year when it is both agreeable and of very great importance that we should have all the sunshine we can get in our rooms.

I think this want of sunshine is often the cause of much sickness and lack of vigor.

PUBLIC SCHOOLS OF PHILADELPHIA.

On the Screen (see Fig. 29) you have the plan of one of the elegant new school-houses of this city.

Please be kind enough to apply to it some of the principles we have been studying, allowing me just to remark that there is scarcely any place that requires such care in arranging the ventilation and heating as in school-houses.

The young, active, growing brain demands the purest and best air, and is the most sensitive to any foul.

The same remarks that applied to hospitals are applicable in a special manner to school-houses.

As nearly as possible each class-room should open freely to the fresh air and sunlight on every side.

Instead of which it seems to have been the study of those planning these buildings to mass all the class-rooms as much as possible and to surround them with stairs, committee-rooms, etc., so as to cut off a large proportion of the most valuable exposure for light and air.

Not contented with this great isolation from the external currents and sunshine, they are again subdivided by glass partitions which most perfectly cut off all through draughts.

Supposing the wind to be blowing in the direction indicated by the arrow, how completely those in the second and third rooms would be deprived of the benefits of these external currents!

I wish there was some way of picturing clearly to your vision, or

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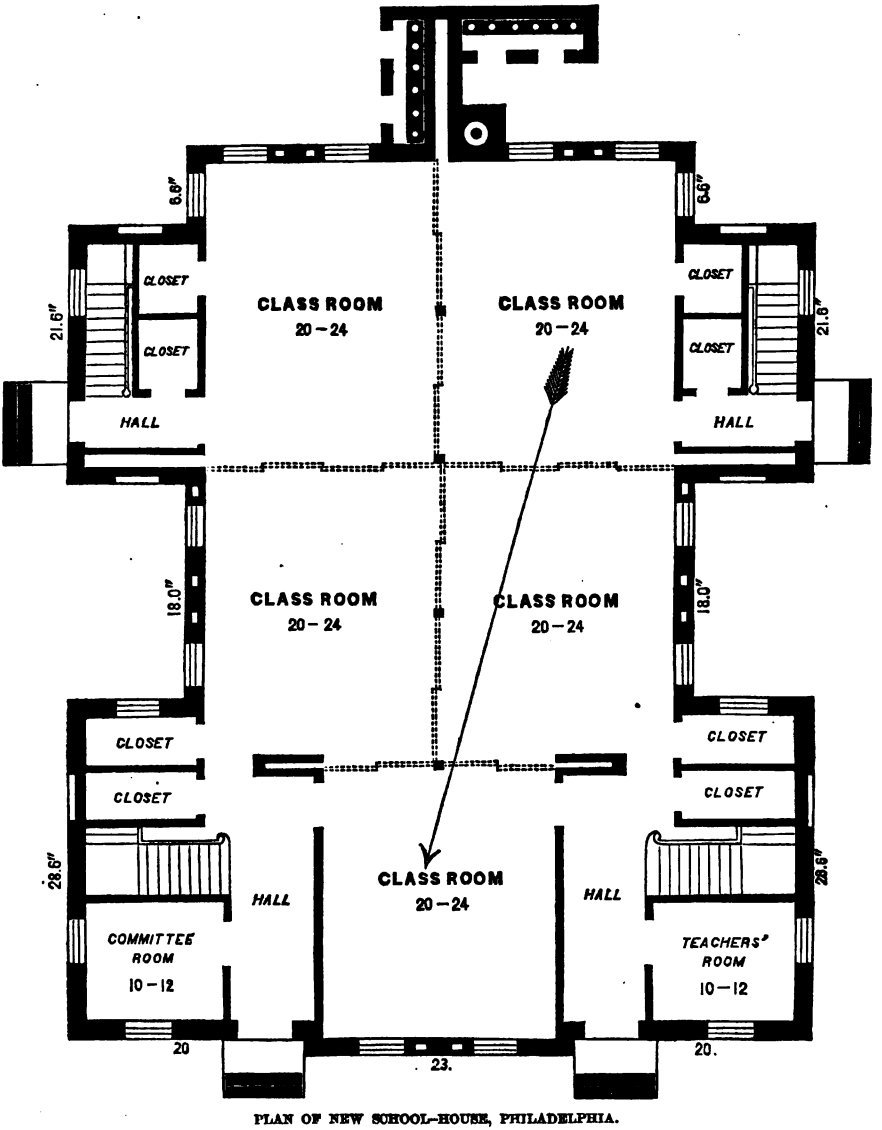
perhaps I should say to the vision of the Public School Commissioners, how poisonous and fœtid that air is as it oozes through from

Fig. 29.



PLAN OF NEW SCHOOL-HOUSE, PHILADELPHIA.

the first class-room to the second, and yet still worse as it passes from the second to the third.

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The air becomes very foul in the first room, much fouler in the second, and—well, what should I say for the third? I don't like to use that homely English word that would express it, I am afraid you would not think it delicate, but I do not think it half so bad to use such words as it is to build such buildings and force our children to breathe over and over such stinking air.

I do not believe, since children commenced learning their A, B, Cs, there were ever erected such a splendid set of school-houses in which those great fundamental principles of sanitary science, sunlight and a free circulation of air, were set at defiance in such a reckless manner, and yet we are going right along, spending hundreds of thousands, and I suppose millions, in erecting these costly and elegant—well, what shall I call them?—if they are used for packing our children in and poisoning and smothering them to death, would Slaughter Houses be a proper term for them?

You may say, "Oh, well, it is not intentional,—these gentlemen don't know any better." Not intentional!—but how much care are we taking to avoid it?

If your physician was to make a mistake in his spelling, or from a misunderstanding of its effects give you a prescription for a violent poison by which the whole family is sickened, would you excuse him by saying it was not intentional, he did not know any better; would you be likely to continue to employ that physician, or would you endeavor to get one who did know better?

If you were to go to any of these School Commissioners to urge upon them the necessity of improving the ventilation of these buildings they would scarcely have patience to listen to you five minutes, and they would be likely to let you know very soon, if they did not tell you directly, that they did not know anything about that thing, and they thought ventilation a good deal of a humbug anyhow.

Now, how long are we to submit to this plea of ignorance as a justification for this great amount of suffering and unnecessary death, where every week's report of the Board of Health continues year after year to tell the same sad story, that half the deaths in the city are caused for want of ventilation?

It is not a difficult matter so to arrange the class-rooms that they shall be exposed to the sunlight and fresh air on all four sides of each room, and further, that each room shall be so separated that the air from one room shall not pass into another.

We give here a plan embracing these characteristics merely as a

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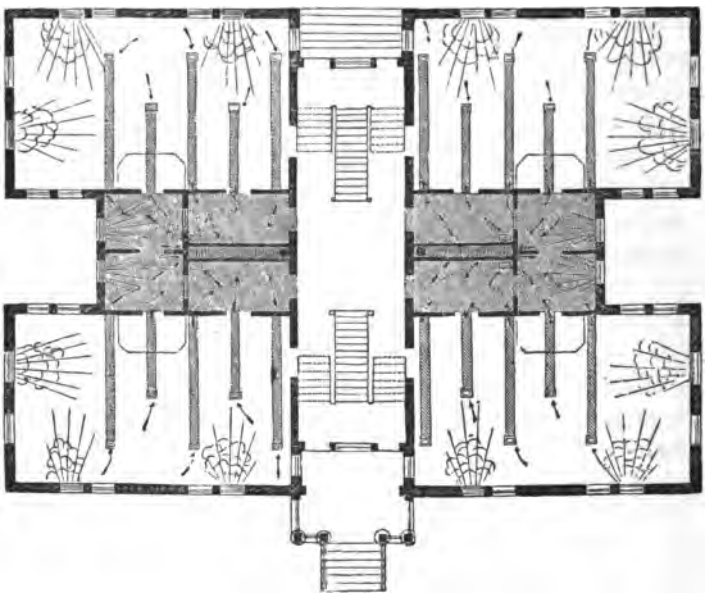
suggestion, which of course would be modified to suit different localities.

Fig. 80.



PLAN GIVEN AS A SUGGESTION FOR A SCHOOL-HOUSE, WITH LIGHT AND AIR ON FOUR SIDES OF EVERY CLASS-ROOM.

There might be objections to so many windows by some of our fashionable ladies who have been accustomed to groping about in the dark, and who have their blinds all closed and curtains down for fear of a little sunlight finding its way in, which might fade their carpets; but as we are rapidly learning that the want of sunlight fades our children's cheeks as much as the sunlight does the carpets, I hope but a few years will be required to give us a wholesome dread of all rooms not abundantly purified every day by Nature's great purifier, sunshine.

The excess of light would, of course, be regulated by blinds—curtains are not suitable, as they obstruct the circulation of air, which is needed in warm weather, and the blinds, when turned, obstruct the light, but allow a free current of air, which is directed towards the ceiling and falls gently diffused over the room; and these should be green, if the architect would allow it, as that is the most pleasant color for the eyes.

As light is thus admitted on four sides, it might be shaded on two

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sides when the glare of the sun was objectionable, and still leave two sides fully open.

The heaters should, of course, be placed on the outsides, and if steam or hot water circulation is used, the radiators should be placed under the windows. With our present patterns of stoves they could not so conveniently be placed there, but might be placed near by, and well supplied with fresh air direct from the outside.

Now, notwithstanding windows are so indispensable for a school-room, yet they alone are not sufficient at all times.

Some artificial power is needed to give a positive motion to the air on still, warm days, and nothing seems better for this, even for a school-house, than the heated shaft.

It will be seen, by reference to the plan, these come in very nicely in the centre of the building where they should be, and where they are easily accessible from each class-room and closet.

A well-diffused ventilation is secured by having a number of registers in the floor, and using the space between the joist as foul-air ducts, and by lowering the ceiling of the closets and teachers' room the foul air can be carried across the joist to the foul-air shaft; the shaded portions on the plan show the direction of the foul air.

If required, one shaft can be made to answer for the whole building, or they may be carried up separately and connected under the roof.

Where steam is used for heating, a coil in the shaft causing the necessary draught, and a stove at the bottom in warm weather, is probably the cheapest and simplest power easily attainable for such buildings. For the escape of foul air, there should be liberal openings near the ceiling, as well as from the floor.

When a large proportion of the heat is from direct radiation, these can be left open most of the time.

To insure perfect success in a crowded school-room, it is necessary to make ample provision for the circulation of a large amount of air. I have in many cases allowed one square foot area of ventilating shaft for each ten children.

This probably is a little larger than would be positively required if the shaft was kept sufficiently heated to insure a strong draught; but the failures in such arrangements very often result from want of capacity.

For the large exhibition room, now considered so essential by many school boards, one-half of the third story might be readily

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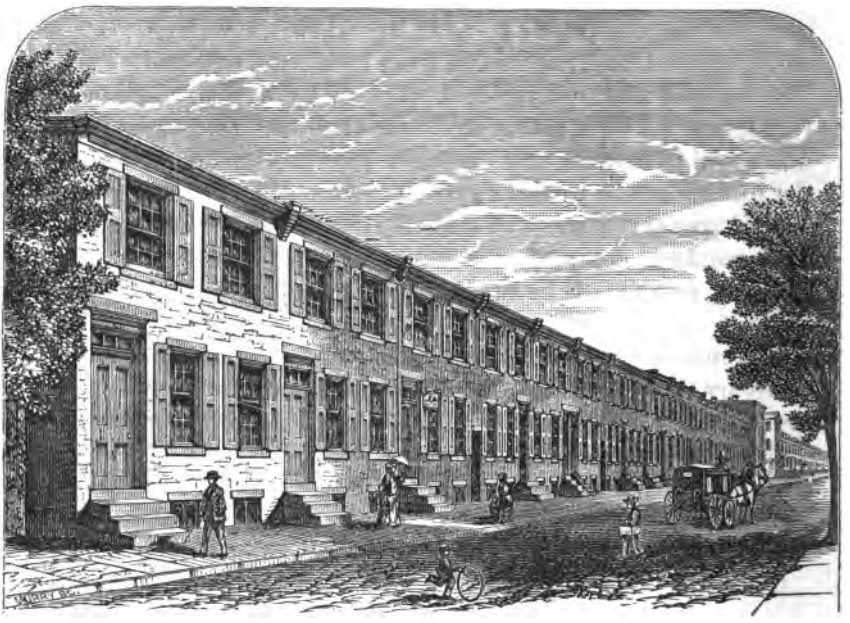
adapted, by omitting the partitions and extending the floor over the recess (by a Mansard roof, for instance); the ventilating flue could be carried across the hall and connected with the other flue in that case.

PHILADELPHIA COTTAGES.

We have here a copy of a photographic view of a row of houses, the peculiar feature of which forms the very strong contrast between Philadelphia and New York—and, in fact, between Philadelphia and almost all other cities in the world.

These small two-story houses, which form the dwellings of so large a portion of Philadelphians, each room having a large window

Fig. 31.



PHILADELPHIA COTTAGES.

and generally a fireplace (I only wish they were open), are scarcely equalled in a sanitary point of view by any other houses for a similar class of men in the world, the Peabody dwellings of London, the Emperor Napoleon's improved homes, or Prince Albert's model houses not excepted.

It is this peculiar feature of the homes of her industrial classes that makes Philadelphians so much more healthy than New Yorkers.

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The situation and natural surroundings of this city are less conducive to health than those of New York.

But let me read here a few lines from a late number of the *New York Tribune*, describing the tenant-house life in that city:

"A person who has never seen a New York tenant-house can form no idea of them. They are usually eight stories high, including the basement, and built two on a lot which is only 100 × 25 feet in size.

"The basement is usually crowded with families, and sometimes the cellar underneath, lying below high-water mark, and frequently flooded by the tide, swarms with squalid women and children burrowing in miasmatic lairs.

"A hall about 3½ feet in width runs through the centre of the building, dividing it into two tiers of apartments on each floor from basement to attic, and these apartments are subdivided into front, middle, and rear, making six suits on each floor.

"The first floor fronts are often used as low groggeries, with the families of the owners living in the rear of them, and the remainder of the building is packed six families on a floor to the roof.

"These houses are sometimes built twice, and even thrice, as deep as the one we have been describing, with six, and even eight suits of apartments on each side of the hall, making from 12 to 16 suits to a floor.

"The expression, 'suits of apartments,' will be certain to mislead the reader as to the real character of the rooms in which these people live, without a special statement on the subject. They should really be called *sets of dens*. They usually consist of two rooms—a living-room and a sleeping-room; the first being about eight feet by ten, and the second seven feet by ten, and averaging seven feet in height. The bed-rooms have no ventilation except what they get through the door opening from the living-room, which has no ventilation or light except what it gets through the door and window opening into the narrow hall.

"This so called living-room is used to cook and wash in, and is also frequently used as a shoe shop, tailor's shop, and for other manufacturing purposes.

"Not unfrequently two families, and even four, live in one of these small sets of dens, and in this manner as many as 126 families, numbering over 800 souls, have been packed into one building, and some of the families taking boarders and lodgers at that.

"Around many of these tenements, or in close proximity to them,

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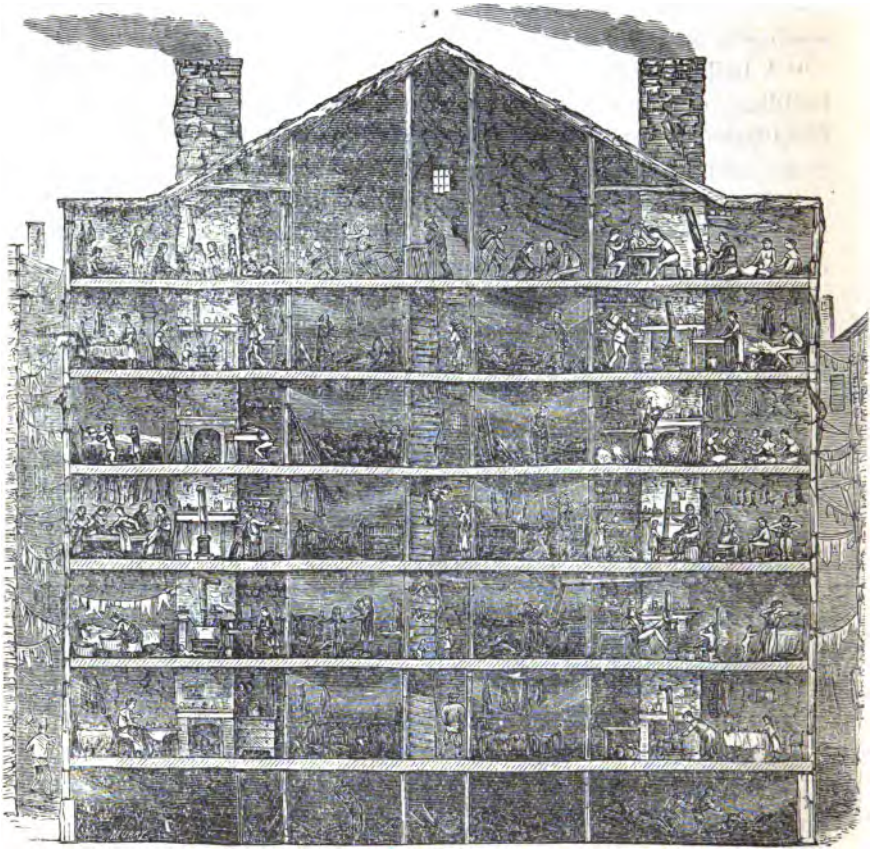
are slaughter houses, stables, tanneries, soap factories, and bone-boiling establishments."

For further illustrating the subject, I have introduced here copies of the plans and a section of a tenant-house on the rear end of a lot on Mulberry Street, near Chatham.

I had these made for the "Technologist" for February, 1870.

The artist in making his sketches visited each story, surrounded by a crowd of inquisitive and rather belligerently inclined spectators.

Fig. 32.



SECTION OF A NEW YORK TENANT HOUSE.

For a further description of this building, and an account of the high rate of mortality among its inmates, see the above-mentioned journal.

What a contrast!

It seems a little remarkable that two cities so close together, with

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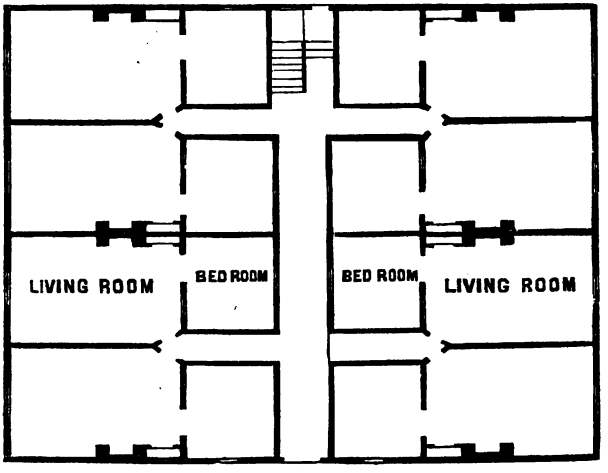
such frequent communication between their inhabitants, should have adopted styles of buildings so entirely different. But the great dissimilarity is probably owing to the respective peculiarities of the ground on which they are built.

Philadelphia had the opportunity of spreading in all directions from the original centre. New York, having commenced on the extreme end of a narrow neck of land completely surrounded by water, its expansion was confined to this narrow strip in one direction, hence the temptation to the excessive crowding found there.

Now, it is a very difficult matter to improve, or, I should say, to make the ventilation perfect in those great masses of buildings in which more than half of the New Yorkers live, and of course it is entirely impossible to get the direct rays of the sun into those dark, gloomy bedrooms, the walls and furniture of which must be con-

Fig. 33.



PLAN OF A NEW YORK TENANT HOUSE.

stantly absorbing and becoming more and more saturated with the foul, fœtid poisons of human exhalations.

And, as the intelligent sanitarian but too well knows, these unsunned and unaired rooms become veritable pest-houses, distributing and dealing death and dismay to the poor, unfortunate, and often ignorant occupants.

But, my friends of Philadelphia, you are neglecting to secure much of the advantage that is thus placed within your reach.

Why were there 6,000 deaths caused in this city last year by foul air, and 2,000 deaths by consumption? Consumption, that purely

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foul-air disease, a complaint so common and yet so entirely and so simply prevented; a disease that is as true an indication of the breathing of filthy air as the itch is of the uncleanly habits of its victim.

A visit to a few of these houses will answer these questions readily. Although their external form and general plan greatly favors the health of the inmates, yet you will find an entire absence amongst the occupants of any intelligent appreciation of these advantages, or any effort on their part to provide an adequate supply of pure air; you will find nine out of ten, or perhaps nineteen out of twenty, closed just as tight as the ingenuity of the occupants can make them; and with the perfection with which doors and windows are made to close nowadays, the chances are small of an adequate supply of pure air stealing in through such cracks.

Almost every fire-place will be found closed by a fire-board, with a neat picture over it sealing it air-tight.

And to cap the climax, you will find the room heated by that object so much dreaded by foreigners—the American stove—a little air-tight stove—a stove too small for the room, but the deficiency in its size made up by heating it *white hot* instead of only red.

Not one in one thousand of these stoves will have any fresh-air supply, and but few of them will be provided with water for evaporation.

Now, put a number of people in such a room as this with a smoking lamp—and worse, a smoking tobacco-pipe—heat the same air over and over, and you will have a room that not only a foreigner but any intelligent American ought to dread.

It is here a great reform might be inaugurated so readily and carried forward, by inducing these people to unstop the fireplaces, sleep with their windows open, and, with but little more trouble, each stove might be well supplied by fresh air through a space between two joists, and carried to the top of the stove.

We will throw a view of Paris on the screen, and from the immense number of chimneys seen on all the houses, you can readily understand that an essential of every room for a Frenchman is a fireplace; and when we know that they use them for building fires in, instead of back-grounds for pictures, it is easy to comprehend why they are so oppressed in such a close stove-heated room as described above.

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Now, notwithstanding such a close stove-heated room may be made so uncomfortable, yet I am a great advocate of the stove, when used properly.

(See article from *Manufacturer and Builder*, page 189.)

We will now throw on the screen a view of an old-fashioned house, which is a complete refutation of the idea, often expressed,

Fig. 34.

OLD-FASHIONED HOUSE, SHOWING MORE VENTILATION THAN A WHOLE BLOCK OF MODERN BUILT HOUSES.

that ventilation was a new notion. But the fact is, as you see by these great ventilating stacks used as chimneys, there was more ventilation in one such building as this than in a whole block of some of our very modern houses.

It is the close and tight room that is the modern invention. And now, let us resolve to "think a little" about the very important subject of supplying our buildings with pure air, and a comfortable genial warmth.

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VENTILATION.

THE GRAND PRIZE AWARDED AT THE PARIS EXHIBITION.

ADDED to the many other gratifying signs of a rapidly increasing interest in the all-important subject of the proper supply of pure air to our houses, is the awarding of the grand prize of the Paris Exhibition to Dr. Evans, for an American sanitary collection.

The Sanitary Commission, during our late war, acted upon the principle since expressed by the report of the Board of Health of New York. They say: "And viewing only the causes of preventable diseases and their fatal results, we unhesitatingly state that the very first sanitary want in New York and Brooklyn is VENTILATION —ventilation supplied in all existing tenant-houses, work-rooms, school-rooms and places of assemblage—and in all that shall hereafter be constructed."

The early recognition during the late war, both by the Sanitary Commission and the government officials, of the important fact that many more men are killed by breathing foul air than are killed by the enemies' bullets, led them to use very active exertions to secure good ventilation in hospitals and camps, and to teach the men themselves the value thereof. The result has been highly satisfactory. The fact that we must make some positive provision for a constant supply of fresh air to every occupied room, and not rely on accidental cracks and openings, is now very generally felt. The simple, practical and efficient means used by the government has done much towards creating this wholesome public opinion.

The annexed plan (excepting a stove and twelve beds, omitted from centre of plan, indicated by the space) is a copy of one I furnished the Committee; and which was faithfully executed in preparing one of the models of hospitals, the arrangements of which have been so highly appreciated, and has shared one of the grand prizes at the Paris Exhibition.

It is a representative plan, showing the general arrangements of wards in a large number of the hospitals.

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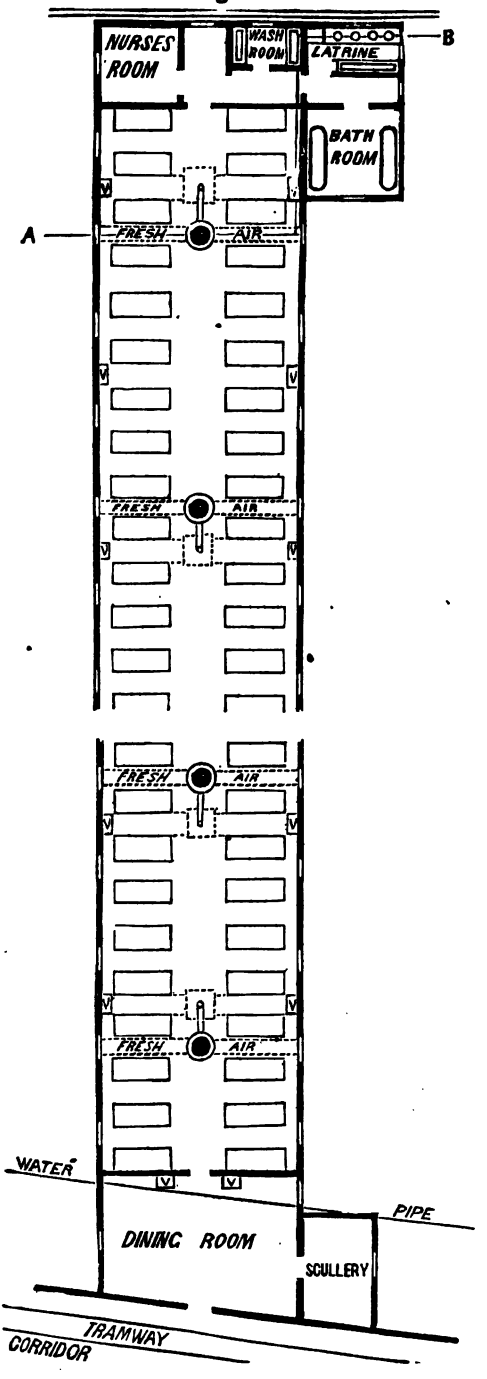
Fig. 35.



The special arrangements of flues, V, for winter ventilation, and the introduction of the fresh air around the stove, were not introduced into the hospitals in Philadelphia, built at the commencement of the war. And the subsequent orders of the Surgeon General and Quarter Master General for the introduction thereof were protested against by the Surgeons of Philadelphia, owing probably partially to their proverbial objection to changes of any kind, and partially to that dread of "ventilation" made but too popular by the many erroneous theories which propose to introduce the fresh air directly into the room, and at times, too, when it is even below the freezing point, without first warming it. These arrangements, shown in the accompanying plan and section, were thoroughly tested, however, in many of the hospitals subsequently built in many of the Western cities.

The plan of ridge ventilation, shown in the accompanying section, I applied first in St. Louis, in the summer of 1863. It is

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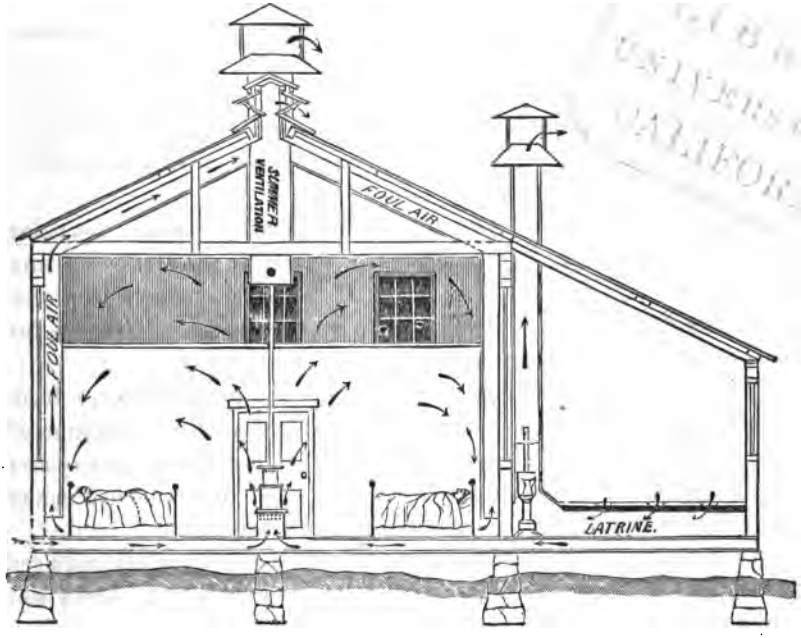
the principle of the Emerson ventilator applied to ridge ventilation. Much trouble had been experienced with other forms on account of their allowing the storms to beat in, and the difficulty of opening and closing them with the various changes of wind; this form fully remedies those objections, and can be left open without inconvenience at all times while snowing or raining. It uses the force of the wind, whenever there is a current passing over the top of the building, for sucking the air out of the ward, because the air in passing across the top of the building is deflected from the straight line by the angle of the roof-board, which creates a partial vacuum in the space below, which, with the friction of the passing current with that coming out of the ward,

Fig. 36.



makes an outward draught, varying in proportion to the velocity of the external current. This is often very useful, especially in summer, when there is not sufficient difference between the external air and that in the ward to create a current. There is often a considerable force in the passing current at the top of the building when there is much less below.

But of course these openings had to be closed in winter to prevent

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all the heat from escaping. It then became necessary in wards that had no fireplaces, to make something as substitutes therefor. Wooden shafts or flues were made to answer this purpose.

I at first made large wooden boxes, placing them in the centre of the wards, and allowing them to extend down to within twelve or eighteen inches of the floor. This was of great advantage, but as the true principle of ventilation is to have an opening for the exit of the contaminated air at the feet of each occupant of a room, or at the head of the bed of each patient in a hospital, it was soon observed that these shafts were too few and far between to make a very perfect arrangement.

The necessity for providing for the escape of the foul air from the level of the floor in winter, so as to utilize the heat, was, after much opposition, finally established and officially acknowledged by the government officers. Then arrangements were made for its introduction into the government hospitals in a more perfect manner.

I believe in no case, however, was it so fully carried out as to place a ventilating flue between each bed, but in some they were arranged, as shown (marked v) in the accompanying plans between every other two beds.

These flues were carried together and extended through the ridge of the roof and capped as an Emerson ventilator; the opening into the large flue, extending to just below the ceiling, was closed in winter at all times, excepting when the room was too warm. This was for the exhaust, but of no less importance was the supply.

The popular dread of ventilation arises in a great measure from the supposition that good ventilation implies a strong draught of cold air upon your back or feet or some other unfortunately exposed place. Such an unfortunate occurrence must be fully remedied in any system of ventilation before it can become popular.

As the simplest way of getting at this, all the fresh air required to supply the partial vacuum created by the exhausting shafts was brought in around the stoves, and partially warmed before entering. At the first the stoves were entirely encased, and the fresh air allowed to encircle them completely, but experience soon demonstrated the desirableness of having a portion of the hot stove exposed for direct radiation, so that the feeble and chilly ones might come near to it and warm themselves. There should always be a considerable amount of direct radiation in every hospital; that from an open fire is the best, but that from a stove or steam-pipe is very good.

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Arrangements were also made for the evaporation of a large amount of water.

As the first winter approached after the commencement of the war, the idea seemed almost shocking to me of putting the sick and wounded men in such open barracks, generally without plastering, and made, as many of them were, with rough boards and very open.

But experience soon taught me the very great superiority of these light and airy buildings over many of the elaborately finished, dark, air-tight structures, such as hotels, colleges, new-fashioned asylums, &c., which the government was compelled to take for hospital purposes.

In fact, when completed with the ventilation as above described, with the abundant sunlight on both sides, without any obstructing partitions and abundantly warmed in winter, and with the proper supply of moisture, they made undoubtedly the most comfortable and wholesome class of buildings, as a whole, that have ever been erected for hospital purposes, not excepting even many of the recent elaborately finished buildings, where not unfrequently too much dependence has been placed on the very meagre and insufficient effect produced by attempts at artificial ventilation, instead of relying more upon the great natural means of ventilation—an abundance of large open windows, open fires and good ventilating stoves.

The ventilation of the latrines or water-closets of a hospital, as well as any other place, is a matter of great importance.

In the spring of 1863, I had put up in a hospital in Washington a ventilating shaft for the latrine room, similar to the one shown on the plans. This was an experiment, but it proved so satisfactory that it was subsequently ordered to be applied in all the principal hospitals.

The difficulty in the isolated wards was, that it required a separate fire in each shaft in the summer. Where it is possible to get it near the kitchen or bake-oven fire, that answers a splendid purpose; but in the single wards it is not necessary to keep up a constant fire; a few sticks of wood every morning answer the purpose of keeping the air in the shaft warmer than the surrounding atmosphere, which, of course, creates the proper draught.

These shafts were made very large—never less than thirty inches square, and sometimes three feet by six feet. The popular plan of opening the water-closet windows and allowing much of the fresh air to enter the building that way was strenuously avoided; the windows

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in the closet were fastened shut, and then the air to supply this large exhaust shaft was drawn from the adjoining ward or room, which ventilated that ward and prevented any unpleasant odor from the closets returning into the ward.

Wherever it was possible, a sheet iron or cast iron pipe was carried up into the centre of this shaft from the kitchen, laundry, bakery or any other constant fire, and where no heat from a permanent fire or from a steam coil could be obtained, a small stove for the purpose was provided.

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[From Sloan's *Architectural Review*, March, 1869.]

THE VENTILATION AND WARMING OF THE MUNICIPAL HALL, PITTSBURGH, PA.

That there should be some artificial force, or power, used to produce the proper movement of the air, in any occupied building of considerable size, is now universally admitted.

But as to the best manner of applying that force, opinions differ greatly.

Many engineers think that there is nothing equal to a fan for forcing in the fresh air, and, in addition to that, some use a fan for drawing the foul air out.

Others prefer to depend upon the movement caused simply by a variation of temperature; and consider that the same amount of heat required to run a steam-engine, to drive a fan, if applied directly to a well-constructed shaft, will move a larger amount of air, at a much less cost, and in a more gentle, uniform manner, causing less unpleasant draughts.

There can be no doubt of the possibility of adjusting the velocity of the fan, and so distributing the inlets and outlets of the moving air, and proportioning the sizes of such openings, that, by skilful management, almost any effect desired could be produced.

But, as the traveller on the road, asking if the direction he was going would take him to Boston, received for answer, "Yes;" but on inquiring the distance to that town, was told that "it was a little more than twenty-three thousand miles in that direction; but, if he would just turn around and go the other way, it would be about ten miles"—so, while there is no doubt of the possibility of moving the air in any direction, or with any velocity, we please, by fans and steam-engines and skilful engineers, yet, if there is a shorter and easier way of accomplishing the same object, let us turn around and go that way.

We should understand, in the beginning, that all artificial warming and ventilation is, we might almost say, a great nuisance. It is certainly much trouble to supply an abundance of fresh air, properly warmed in cold weather, and so distributed as to create no unpleas-

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ant draughts in any part of the building; and, as changing its temperature materially detracts from its freshness and purity, it must necessarily be inferior to the natural condition of the external atmosphere. But, until we get to migrating, as the birds do, in spring and autumn, so as to keep in a warm climate, we shall have to continue supplying ourselves with artificial heat, no matter at what cost of money and care; and it is almost time for us to commence making an attempt at supplying ourselves with partially pure air. We should take the natural conditions of the atmosphere for our guide, as far as possible. Man is an artificial animal in many respects. He can thwart or reverse some of the minor laws of his creation, but frequently pays heavy penalties therefor.

To be sure, in all our buildings the warming of them and their ventilation are almost entirely artificial; but we should endeavor to imitate, as nearly as may be, the action of the great source of heat and motion—the Sun; and the nearer we can imitate and follow the natural movement of the air, the nearer we will come to perfection. By reference to the accompanying plans, it will be seen that all the heating, both by direct radiation and air currents, is placed around the exterior walls, at and below the floors; because, in the first place, we want the greatest amount of heat where the greatest amount of cold is, so that they will neutralize each other, and produce a uniform temperature over the whole room; secondly, the inlets of the fresh air are on the exterior, and the outlets for the foul are mostly towards the interior, because the Central Hall in this, as in all other cases, is the great natural ventilating shaft. Although it is very necessary to have other ventilating shafts, that can be definitely controlled, for special and specific purposes, yet, in a large public building, with the doors opening and closing continually, it is impossible to prevent a great central shaft, of that immense height, from becoming a grand ventilator; and, when all other arrangements are made in accordance with this fact, it is very desirable that it should be so.

Now, if the arrangements for heating were placed in the interior, and near the hall doors, as is usually done, then the moment those doors were opened, the heat would rush out there, and the cold air would suck in at the opposite windows, sweeping across the whole room to the hall, chilling every one in its passage, and causing universal dissatisfaction and complaint.

But, if the floors and exterior walls can be kept to about the

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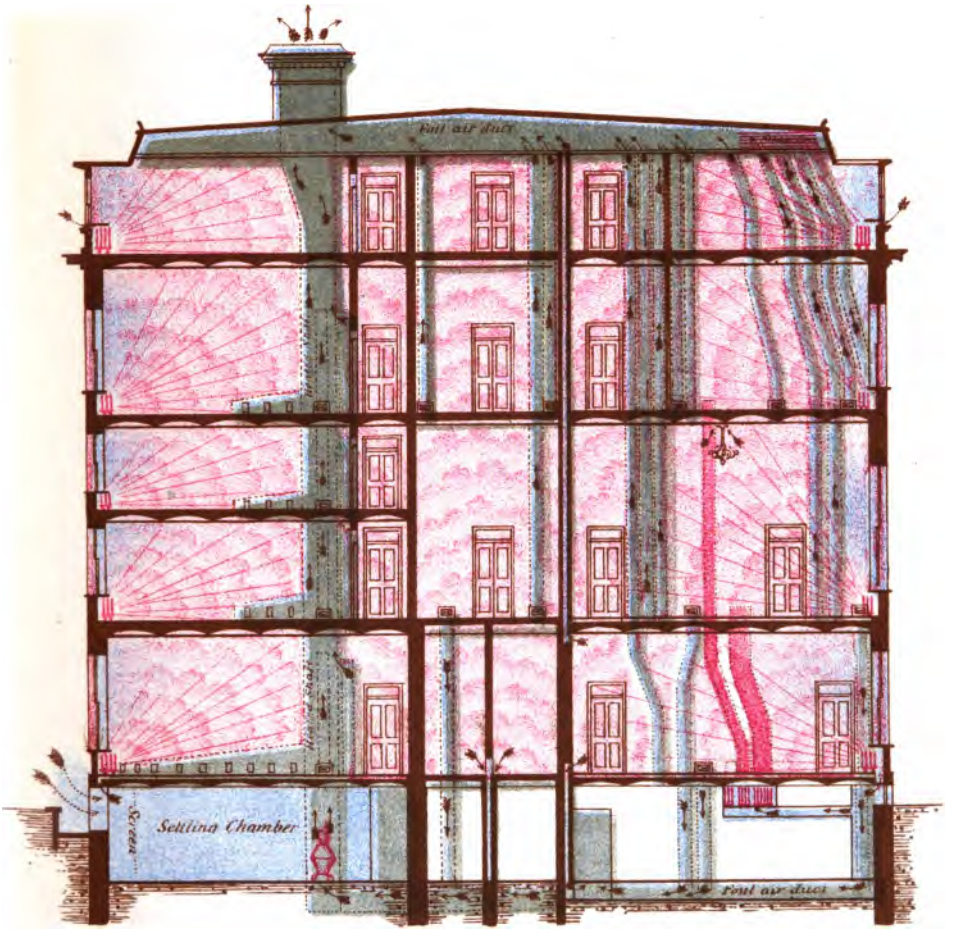

J. W. Kerr, Arch.

SECTION
Showing
VENTILATION & HEATING
OF THE
MUNICIPAL HALL, PITTSBURGH, Pa

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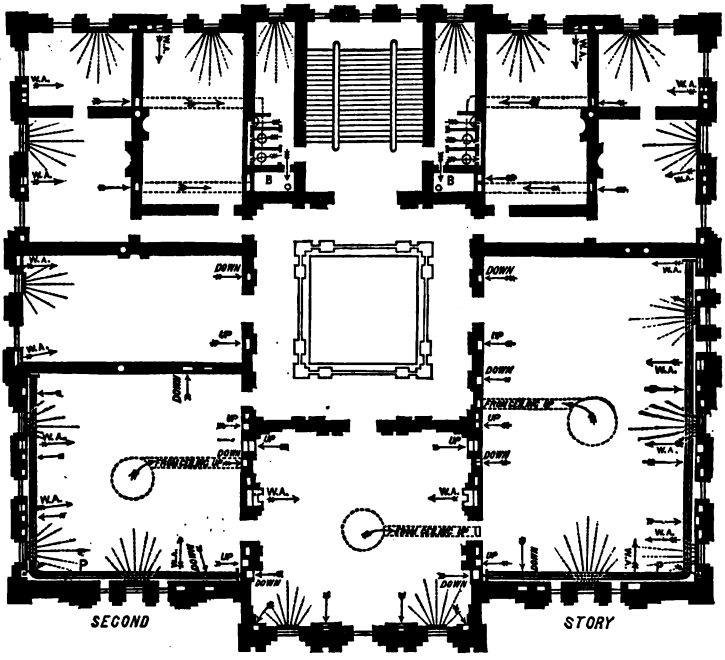
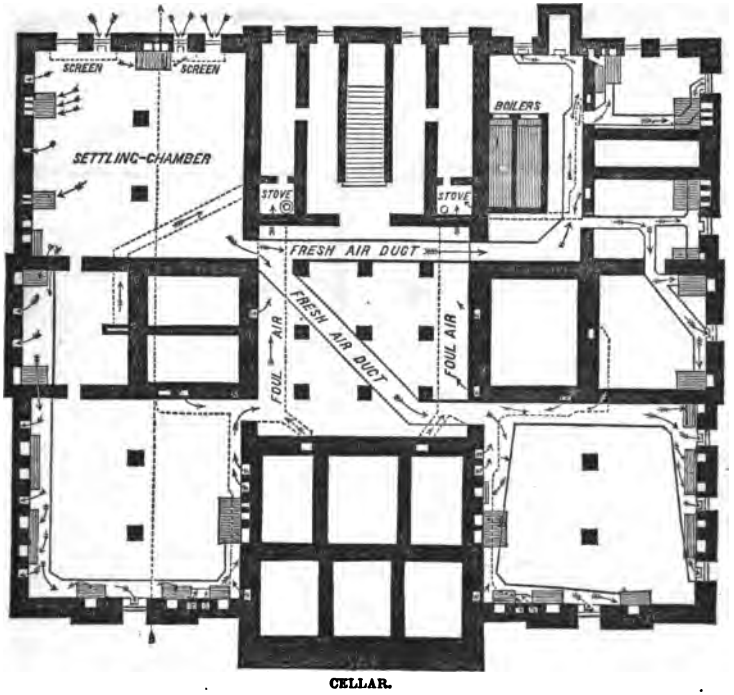
Fig. 37.





CELLAR.

MUNICIPAL HALL, PITTSBURGH, PA.

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temperature of the body, 98°; and if the excessive cold of the windows is counteracted, by steam radiators under them, then the transoms over the doors may be left always open, and even the doors themselves could be safely left open much of the time, forming a liberal and excellent ventilation.

If, however, we should allow the main hall to become the ventilator for the water-closets, the boiler-room, etc., it would be an offence to the whole building. Separate ventilating shafts must, therefore, be provided for these; and it is also necessary to have a separate arrangement for the ventilation of each room, in case it is desirable to close it entirely; and thus disconnect it from the main hall.

For this purpose, two large shafts have been provided by the architect, communicating most directly with the water-closets, and by direct or lateral ducts with exits in the floor of every room in the building, as well as with exits directly over the chandeliers in the ceilings in the principal rooms.

There is another advantage to be gained by the use of these shafts: In spring and autumn, when the external atmosphere is too warm to require sufficient additional heat to cause the necessary motion of the air, and yet too cold to allow of the windows being open; then, by heating the air in these shafts, by steam-coils, if the boilers are in use, and if not, by an ordinary stove or furnace that will be placed there for that purpose, the air will be set in motion over the whole building.

It is just at this point that the closest comparison should be made between the values of the fan and the heated shaft for moving the air, because in winter, when there is a considerable difference of temperature between the external air and that in the building, all the flues draw freely, and it is very easy to keep up sufficient circulation; and in summer, when the windows are all open, a fan would be perfectly useless.

The ventilating shafts, as shown on the plans and section, commence at the foundation, four feet by seven in the clear each, the two giving an area of fifty-six feet.

Their capacity is increased thirteen square feet each, where the additional foul-air ducts enter, above the fourth story, thus giving an aggregate of eighty-two square feet of ventilating flue.

Now, we want to know how much air these shafts will move, and how much coal will be required for the purpose.

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Of course, in making these estimates we lay aside all other sources of motion, such as the artificial heating, external currents, etc., and suppose the air in the building to be perfectly stagnant. Such conditions would scarcely occur six days in a whole year, but then those six days must be fully provided for.

One pound of coal will heat from thirty to forty thousand cubic feet of air 10°. Now we find, theoretically, that a temperature of 10° in excess of surrounding atmosphere, will give, in a chimney one hundred feet high, a velocity of more than eleven feet per second. Suppose, then, we allow the six feet for friction (which would be larger than necessary in a flue of that size, made perfectly smooth), we still have five feet per second for the velocity of the moving current; and this, I believe, will be generally exceeded in practice. Eighty square feet for size of shafts, with a velocity of five feet per second, gives 24,600 cubic feet a minute, or 17,000,000 (omitting the fractions) in a day of twelve hours. This would be an abundant ventilation for this building.

Now, to warm these 17,000,000 cubic feet 10° in the shaft, for the purpose of giving it this motion, would require only 566 pounds of coal, supposing 30,000 cubic feet to be heated by one pound, which is a small allowance.

Let us compare this result with that of the fans in the Capitol at Washington, probably the most perfect in construction of any in this country, if not in the world. According to the report of the engineers, they burn, in summer, for running the fans for ventilation, 3,000 pounds of coal in eight hours. This supplies the two engines, one of 30-horse power to drive the fan for the House of Representatives, and one of 16-horse power, for the fan of the committee rooms, etc.

I have never seen the record of any accurate experiments, giving the actual amount of air delivered; and the amount, as guessed at by different parties, varies greatly. Some give it as high as 60,000 cubic feet per minute for the large fan, and 30,000 for the smaller one. But the engineers say that 40,000 for the larger one, and 25,000 for the smaller, is quite as much as they ever deliver per minute, in practice. This, for the eight hours they are running, gives 31,000,000 cubic feet, or a fraction over 10,000 cubic feet of ventilation for every pound of coal burned, instead of the 30,000 delivered where the heat is applied directly to the shaft.

Now, this saving of the two-thirds of the coal is but one of the

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very small items in favor of the heated shaft, as compared with the fan. The fan requires the constant employment of a competent engineer, in addition to the fireman demanded in both cases.

We must consider, as above stated, that there are scarcely six days in the whole year during which such a stagnation occurs as would require the whole power of the flue. There is much of the time when the motion of the external current, or the difference of temperature within the building and out, would produce the required ventilation without any special additional heat. Also, whenever the fires are going in the boilers, the waste heat from the smoke-pipe would cause an abundant circulation. And thus the shaft, under all such circumstances, would be doing its work quietly and efficiently, night and day, without any trouble to or assistance from any body or thing. But the fan would be quite useless without the constant attention of the engineer.

Although it may be possible so to adjust the inlets and outlets of the moving air, and the velocity of the fan, as to avoid unpleasant currents and not to create an undue pressure; yet, in practice, this is found to be so difficult that it is seldom accomplished. If the outlets, from any cause, become partially closed, the power of the fan is such that it drives in the air until it becomes compressed, like the air of a diving-bell, inevitably causing headache.

I think the gentle motion given to the air by the few degrees difference in temperature, very much pleasanter, and not liable to any such abuses.

An effect will be produced, however, with just as much certainty, in proportion to the power used.

Taking all things into consideration, I think the heated shaft is at least ten times as valuable, for the purpose of ventilation, as the fan driven by the steam-engine.

Attempts to use the heated shaft have been frequently made by persons who knew nothing about the principle of ventilation, and, of course, have very commonly failed to produce the effect contemplated. But, because an ignorant man burns his house up by the improper use of fire, it is scarcely probable that we shall all discard the use of fire in our houses.

There are several important errors frequently made in the application of the heat to the shaft, and in the general application of the shaft itself to the ventilation of the building.

I think, in the shaft or towers by which the Houses of Parlia-

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ment are ventilated, a large proportion of the foul air is caused to pass through the fire, at the base of the tower. This requires an extravagant use of fuel. It should be burned in some furnace or enclosure of fire-brick, or other non-conducting substance, with a slow draught, so as to secure, first, thorough combustion, after which it should be allowed to heat the air in the shaft to a small degree, because while an additional temperature of 10°, in a shaft fifty feet high, would produce a current of eight feet per second (less the friction), it would require a temperature of 200° to produce a motion of thirty-six feet per second, or it would take twenty times the coal to produce between four and five times the effect.

To work economically, therefore, the flues should be large enough to produce the desired results, with a very moderate velocity.

Another fatal error, now detrimental to many of our large public buildings, is to place the coils of steam-pipe, or other arrangements for heating, at the top instead of the bottom, with the expectation that the cold air will be so accommodating as to flow up there itself to get warmed, before being turned out of doors. Instead of which the air from above falls in on one side, is heated, and is thus driven out on the other.

I have noticed, in many large public buildings lately erected, that attempts have been made to draw down the foul air from the third and fourth stories of several detached buildings, and from thence to conduct it, by one underground duct, to the engine chimney, at a great distance.

Such complicated and bungling arrangements will, of course, prove failures; because, when the wind blows hard on one exposed building, it presses down the duct with great force, entirely overcoming the draught from portions of the building less exposed; and the foul air, from the windward side of the house and the main duct, is often pressed up into the rooms on the leeward side.

Another very common error is to have a flue very large in some places, but greatly throttled in others, as in the House of Refuge in Philadelphia, where an immense ventilator was put on the roof, equal, probably, to thirty or forty feet area; and, emptying into this, were four long horizontal shafts, made of rough boards, only one foot square each, giving an aggregate of four square feet; but on the top of the roof, for the public to look at, was the ventilator aforesaid.

I have been informed that this was about the manner of execut-

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ing the ventilation (so called) in the new school-houses in Philadelphia, where they attempted to use the heated flue, and kept up a fire to create a draught.

The chimney was all right, what there was of it; but, in making the connection with the chimney between the floors, there was only the width of a single brick left out, or probably not a tenth part of the space there should be.

Of course all such arrangements as these, besides being a disgrace to the profession, and a great injury to the cause of ventilation, are stumbling-blocks in the way of the casual and superficial inquirer for the best system.

There are so many causes rendering one flue liable to interfere with another, unless carried the entire distance by a separate tube, that it is undesirable to extend the system of flues to a very great distance, especially in a horizontal direction; and in practice I seldom find any occasion for doing so. It is nearly always possible to find some corner, or space of little value, that can be spared for the purpose, at frequent intervals throughout the building.

It is a very good plan to place the ventilating shaft in the immediate vicinity of the water-closets. All the pipes for hot and cold water may be carried up therein, as well as the soil-pipes and, perhaps, rain-water pipes also.

They are thus very convenient for attachment and repairs, and always kept from freezing while the building is occupied. By reference to the accompanying plans and sections, it will be seen that it is proposed to take some of the flues from the floor of the first and second stories down to the cellar, and let them enter the heated shaft at that point. These will draw off the coldest air of the rooms, and it can, consequently, be drawn down with the least force.

The flues from the top of the rooms, which are liable to be heated excessively by the gas-lights, and the flues from the space immediately under the floors—which it is also proposed to have a little warmer than the average temperature of the room—are all carried directly upwards, and enter the main shaft near the top.

It is proposed to have a coil of steam-pipes in the horizontal air-duct over the fourth story.

Although this is heating the ventilating flues at the top, which was so strongly condemned above, yet, in this instance—as it is placed so far from the main shaft, and these flues are in the centre

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of the building, and mostly warmer than the rooms—it is believed that it will be easier for the vacuum created by the heat to be supplied by the air flowing up these flues, than in any other way. In that case there would be no return current.

The supply of the fresh air to this building was a matter of much solicitude, as, from the immense amount of bituminous coal burned in Pittsburgh, indicated by the dense clouds of smoke belching forth from its forests of factory chimneys, the whole air is filled with soot.

If a window is raised to let in the fresh air, in a few moments every thing in the room is covered with particles of soot, some small and some not small.

It is, therefore, proposed to use a large room in the cellar, thirty-six feet square and twelve feet deep, for a settling-chamber, and allow all the air for the whole building to enter that way, through fine wire screens, which will catch some of the largest particles of soot floating in the air.

These screens will be so arranged that they can be swept down or cleaned every morning, and probably brushed over with oil to assist in catching the particles of soot.

In cold weather most of the fresh air that is required for ventilation throughout the building will be slightly warmed by passing over steam-pipes in the cellar.

It is not designed to *heat* this fresh air, but merely to warm it to 50° or 55°, to prevent its forming unpleasant cold currents as it enters the rooms. The additional warmth required will be supplied by direct radiation, from the steam radiators shown under the windows, and the slightly augmented heat proposed to be given to the floor by the steam-pipes under them.

This proposition of warming the floors so as to keep the feet warm, and allow the head to be surrounded by cool, fresh, invigorating air for breathing, is believed to be of much importance.

It is so contrary, however, to the prevailing custom, which is to keep the head in an atmosphere of from 70° to 80°, while the feet are from 50° to 60°, that it may take some time to become accustomed to it, and ascertain the most desirable temperature to keep the floor at, which is probably that of 10° below the temperature of the body—say 88° or 90°—which would feel cool to the touch, and perhaps be found most agreeable.

It will thus be seen that great care has been taken to study the

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natural movements of the air in the building, and to work *with* these currents, and never to oppose them in any important particular.

All excessive draughts have been carefully avoided; yet, while it may be almost impossible to discover any perceptible currents of air in any of the rooms in passing through them, yet it will be also almost impossible to find any stagnation of the air in any parts. The heating surface is so distributed throughout the edifice, with the excess of heat to meet the excess of cold, that if all the doors are thrown open over the whole building, there will be an even, uniform temperature throughout. Or, if the doors should be all shut, with fire in the ventilating stacks, the constant motion of the air will be equally well secured in that way.

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[From *The Manufacturer and Builder* (New York) for April and May, 1869.]

VENTILATION AND WARMING.

CAST-IRON STOVES.

THAT great American institution, the cast-iron stove, is in disgrace. It has been, we think, unjustly and unmercifully persecuted. There is a strenuous effort being made to exonerate ourselves from just censure, merited by our many sins of omission and commission, by endeavoring to cast the blame upon this most faithful servant of almost every laboring man's home.

That great and successful laborer for the improvement of American homes, A. J. Downing, devoted no stinted portion of the brilliant delineations of his gifted pen to the unmeasured condemnation of this peculiar American institution. Charles Dickens's fertile brain seems almost exhausted in gathering up expressive adjectives of condemnation to hurl at that "eternal, accursed, suffocating, red-hot demon of a stove, so commonly found in America."

This Dr. Harris quotes approvingly, and thinks the better health of the foundling hospitals of Paris is because this "accursed stove" is unknown in those public institutions.

Catherine E. Beecher and an unnumbered host of other very able writers strive not to be outdone in condemning the poor object that they suppose to be the great source and cause of those foul-air diseases that seem to have increased so fearfully of late and are causing such devastation in our modern American homes. Now, add to all this Dr. Derby's very able arguments, intended to call attention to the great harm probably arising from the escape of that intense poison, carbonic oxide, from burning anthracite coal, and the very learned discussions and experiments of the French Academy of Sciences showing that the virulent poison pays no attention to the simple, crude attempts to confine it by cast-iron, but passes through such obstructions at will, with almost as much ease as a squirrel would through a post-and-rail fence; and after all this, one can scarcely perceive what will be the result of attempting to plead its cause, to advocate the general or almost

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universal use of this despised and persecuted article, the American stove.

But we will do it, not in the interest of the stove manufacturers —for we have no friend in the business, and the stove is too much in disgrace to afford to pay for its advocacy in that way—nor yet from mere compassion, as many take the part of any persecuted object, but from sincere conviction of its intrinsic worth, because it is our belief that its universal use, if used properly—not abused —would be of inestimable value to the American people. We believe they are of much more value to us than all the gold mines of California and Nevada. The value of the shipping that sails from our ports and dots the ocean in every clime is but a drop in the bucket compared with the value to us of the proper use of our American stoves. Now, we will endeavor to give our reasons for entertaining an opinion so singular and unpopular.

Accepting as a truth that saying of the great Dr. Franklin, that "Public health is public wealth," and which an eminent hygienist of England lately said should be inscribed in letters of gold over every school-house and public building throughout the land, it becomes a question of the gravest importance as to how the best conditions of public health can be obtained.

We must not take a casual and superficial glance at a few only of the prominent members of society, who by their wealth and position may be able to attract more attention from the public than a whole factory full of men and women who labor from seven in the morning until six at night; because these wealthy men, if they lose an hour, or a day, or even a month by sickness, have no fear of losing their situations and the entire support of a dependent family. But it is the men and women upon whose strong muscles the country is dependent for all its manual labor whose health must be looked after and preserved—it is the health of these that forms the great wealth of a nation.

Now, one of the great fundamental conditions of our existence is, that we maintain a uniform temperature of our body, the standard of which is commonly much above that of the surrounding atmosphere; and this must be secured at all times, or existence itself ceases. Upon the manner of supplying this artificial heat, and the supply of fresh air which more or less accompanies it, depend the health, wealth, prosperity, and happiness of the nation on one hand, and the sickness, poverty, and wretchedness of it on

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the other. In the early settlement of a country, when wood is very abundant, the open wood-fire is not only the cheapest and simplest form of obtaining the required artificial heat, but it is in many respects the most advantageous to health of any known means. But in large cities and thickly-settled countries, wood is too expensive for ordinary use for a large majority of the people—and the wealthy even neglect to use wood-fires, from ignorance, probably, of their real sanitary value. Fires of coal in open grates are the next most simple arrangement, and although not without their inconveniences, yet they have some excellent sanitary qualities; and it is our opinion it would add greatly to the health and happiness of many families, even in moderate circumstances, to have an open fire to sit by, should they have to substitute an old-fashioned rag-carpet to cover the floor instead of a more expensive one.

But notwithstanding the many advantages of the open fires of wood and coal, yet they are expensive, as they consume from two to three times as much coal to produce the same amount of heat in a room as can be produced by a good stove. The question is not so much, Shall the laboring classes use stoves, or shall they have open fires? as it is, Shall they have stoves, or shall they go without artificial heat altogether? If Charles Dickens were to visit the forty thousand paupers said to dwell in one portion only of London, he would not, to be sure, find them crowded around that "peculiar American institution," the "infernal red-hot stove;" but, *far worse*, he would find them crowded together in some cold, damp, chilly room, perhaps a few hovering over some smoking embers, but the majority huddled together in a corner, covered by all the old rags they had left after calking all the cracks of the doors and windows, to keep out, if possible, any breath of air.

Heat is a great and valuable sanitary agent, and if it can be made available more cheaply by the use of the stove than in any other way, it is the duty of the sanitarian to teach the people how to use that, and not to spend his time in abusing it simply for the faults resulting from its misuse. The want of a proper supply of fresh air when heating by the stove is one great cause of this hue and cry against the poor stove. It does, of course, allow a small room to be shut up almost air-tight, and if crowded with filthy people, with a kerosene lamp smoking in the room, there is no doubt whatever that a very foul and offensive atmosphere may thus

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be manufactured. A bright, open fire scarcely allows of this abuse. But it is the simplest thing in the world to remedy all this, and it can be done with the stove much cheaper, and frequently with more satisfaction, than with the open fire. All that is required is to bring in a good supply of fresh air from out of doors, and discharge it on the top of the stove.

But in attempting to do this it is quite strange how many very intelligent persons will commit the fatal error of supposing that all that is necessary is to cut a hole through the floor, and the fresh air will flow up around the stove itself, instead of which it will simply flow out over the floor, being heavier than the air in the room. It must always be conducted to, and discharged on top of the stove, and then it simply falls down and mingles with the heated air arising around the stove. This introduction of fresh air around the stove was very fully explained by Dr. Franklin, and most enthusiastically advocated by him, and he introduced it largely during his lifetime through the world-renowned "Franklin stove;" yet owing to the stupidity or ignorance, or whatever we must call it, of the people as to the value of or necessity for fresh air, this valuable feature of this celebrated stove—in fact, all the *Franklin*—was omitted, and the simple skeleton, without the spirit, handed down with his name.

We have taken much pains to inquire of recent prominent writers who have urged the use of the "Franklin stove" if they knew what a "Franklin stove" was? They are apt to be quite indignant at the suspicion of such ignorance; but on inquiring how they propose supplying the fresh external air to their stove, they want to know what is meant. We have found scarcely a single writer thus questioned who had the correct idea of a Franklin stove. There was a large number of these Franklin or ventilating stoves used during the war, and when to the liberal supply of fresh air was added an abundant supply of moisture, an artificial atmosphere was produced which for genial warmth, freshness, and purity could scarcely be excelled by any artificial means of heating now known. The success of this manner of warming the hospitals during our late war has given a great impetus to the reintroduction of Franklin stoves. Their introduction into the hospitals and barracks of England is urged by the surgeons and inspectors. The Sanitary Committee of the Paris Exposition spoke in the highest terms of this system of heating and ventilation as adopted in the United States.

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Several new patterns of these stoves have been gotten up in Cincinnati, and introduced into the public schools, which give good satisfaction. A modified pattern has been introduced into some of the New York schools within a few months, but with what success we have not heard.

Owing to the necessity in schools of the children sitting very close to the stove, most of those made for such positions are entirely surrounded by the casing, thus forming an air-chamber around the whole stove. This greatly obstructs that portion of the heat that gives the great superiority to open fires and stoves over hot-air furnaces. We mean the direct radiation. The effects of heating by direct radiation and by currents of circulating warmed air are very different. You may be sitting in front of an open fire from which the *rays* of heat will be thrown out so strong that you will be kept comfortably warm, and at the same time there may be a *current* of air surrounding you, and from which you are breathing, which passes by you into the fire at a temperature many degrees below that indicated by the thermometer.

On the contrary, in a room heated exclusively by hot-air currents you are surrounded by and breathing air heated hotter than indicated by the thermometer; because the cold walls and cold windows are constantly absorbing the heat of the solid bodies in the room by radiation.

When we consider how much more active and vigorous the system is when breathing the cold, bracing air of winter than when breathing the warm, debilitating air of summer, we can readily understand how much more wholesome would be an atmosphere in which a large proportion of heat would be derived from the direct radiation of a hot stove or open fire, than where all the air was vitiated by overheating for the purpose of securing the required warmth in that way.

The loud and universal complaints against all hot-air furnaces have fully demonstrated the entire impossibility of producing a comfortable and satisfactory atmosphere in a room by that means only. With the open fire, the highly heated and vitiated air is carried directly up the chimney. Much heat is thus wasted, of course; but this may be far better than the wasting of the health by attempting to breathe it. In heating by the stove, the air that comes in contact with the hot sides, and is thus heated and consequently vitiated, is frequently retained in the room; this makes a

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stove-heated room more unpleasant than when warmed by the open fire. But suppose there should be sufficient ventilation to carry out of the room directly this warmed and vitiated air, and depend mostly upon the radiation from the stove for heating, that would be still much cheaper than the open fire, and far more wholesome than the heat from a miserable hot-air furnace.

The radiation from the hot-air stove acts in all directions equally —one must remember that the rays of heat are thrown as much to the floor as to the ceiling; it is only the currents of warmed and vitiated air that rush to the ceiling, while the currents of cold, and generally purer, air flow along the floor. But if the pure external air is brought in on top of the hot stove, and falls over it, the radiation from the stove is sufficient to keep up an equal temperature over the whole room; and if the supply of air by the stove is sufficient to fill the room and allow for what is carried off for ventilation, there will be no cold air sucking in under the door and around the windows, which creates those cold, unpleasant draughts so much complained of. Now, a word about that dreadful poison, "carbonic oxide," that passes through the iron stove so easily. It is our belief that many hundreds and thousands die every year from the escape of this gas; but practically the amount that escapes through the solid iron is probably a very small fraction compared with what escapes, or rather is expelled, through the open joints of stoves and furnaces, or from open fires, by badly constructed flues. Here is the great trouble with most of our heating arrangements. We believe that poorly constructed and entirely choked flues are the cause of more sickness and deaths in the United States than cholera, yellow fever, and small-pox combined. Few persons who have not made a general investigation of this subject have any conception of the very large number of flues in daily use that are either entirely choked or totally inadequate to carry off the gases and smoke from the fires which they are intended thus to relieve; hence the very frequent annoyance from gas and smoke daily met with.

Let us illustrate by one or two of the hundreds of similar cases met with. Speaking of ventilation at the house of a wealthy gentleman, who had remodeled his old-fashioned country place two or three years before, his housekeeper said she wished I would examine her room in the third story, as the gas was frequently so bad there it almost made her sick. I very soon noticed, on entering the

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room, an appearance of smoke escaping all around the base-board, and, on removing that, found it all black with smoke on the back. A carpenter was at once sent for, and a portion of the floor taken up near the chimney, where there appeared to be the most dense coating of smoke. Worse and worse. Here was the whole underside of the floor and surrounding joist blacked and almost charred. Here we soon discovered an open flue that appeared to be discharging its whole contents of gas and smoke simply under this floor; and with a string and a bit of iron tied to the end of it we traced the flue to the large stove in the hall, which had thus been discharging the whole of its smoke, waste heat, and gas for two winters, and just commencing the third, directly under this floor. On inquiring, it appeared that on remodeling the house, instead of the old-fashioned open fire in each room—which makes the best ventilator in the world—the proprietor thought they must dispense with these great nuisances, and have the whole heated by hot-air furnaces; and of course, when the lady found that there was a great flue alongside of the closet, of no earthly use, only just for a ventilating flue, it was at once ordered to be cut away and the closet enlarged all that much, to her perfect delight. A very common way of utilizing such useless space as ventilating flues! And then the stupid furnace man, finding a hole in the wall, stuck his stove-pipe in, perfectly regardless, as usual, as to where the smoke was discharged, provided it would "draw"—obtained his money and left. There had been no complaints of the draught in this case, as there was plenty of space for it to be discharged into the rooms above.

One more illustration of the great annoyance of carbonic acid gas and carbonic oxide gas passing through the iron of the ordinary furnaces and escaping into the room. A few years ago we bought a new house in Philadelphia, which the builder was to have completed in six weeks. Of course, American like, we were ambitious to live in as large a house as we could possibly raise the money to purchase—and that was small. As houses for sale were scarce in the neighborhood in which we desired to locate, a critical examination was waived until completed and possession given. Afterward, when the flues were examined carefully for the purpose of putting in the heating apparatus, what should we discover but a lot of those little mean Philadelphia flues, four by eight inches, left without plastering, and as rough inside as the face of a limestone turnpike.

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Here was trouble. To live in a house with such flues I knew would be perpetual torture, a daily chronic irritation from escaping gas and smoke, and a constant complaint for want of the proper heat and warmed air for ventilation; but my wife and daughter, as fond as they were of good ventilation, were entirely oblivious to my pleadings as to the necessity of tearing down the entire breastwork and building up new flues. They demonstrated very easily, that, in the first place, we could not afford to go to the additional expense; and, in the second place, it would completely spoil the new plastering, as we did not expect to have the walls painted at once; and thirdly, that the rooms were already so small that we could not afford the additional room to build suitable flues; and we could not do as they do in Kentucky, for the purpose of getting more room, build the chimneys out of doors, from the fact that there was but a brick on edge between our own and our neighbor's flue. Many consultations were held and contrivances suggested for doing what never yet has been done—making all the smoke from a good-sized fire, and a sufficient quantity of warmed air for a good-sized room, go through little rough flues like these.

One fine, clear morning, feeling a little more courageous than common, I ordered the top taken off the chimney and the whole breastwork taken down to the cellar, not leaving one brick upon another of the whole flue-work, and had them built up properly. The enjoyment of good draughts and bright fires fully compensated for all the trouble. I was not at home when the fires were kindled the second winter; but my wife's letters were prefaced with "Carbonic acid—dreadful poison—carbonic oxide—the flues smoke dreadfully," etc., etc. It at once flashed across my mind that I must have been so unfortunate as to have left that little pamphlet of Dr. Derby's lying about, and my wife had got hold of it. I answered that the flues were not sufficiently warmed, but after a little while they would certainly draw better. This was accepted as such sound philosophy that the building up of fresh fires, which filled the house with smoke, and, when coal was put on, with gas also, was cheerfully persisted in. But upon my arrival home, instead of the pure, sweet house I was accustomed to, I noticed at once the smell of gas and smoke, and a very disagreeable odor seemed to have saturated everything—in fact, it smelled like other people's houses. The family said it was not as bad as it was at first; they were getting used to it. My very-philosophical explanation of the cause of the

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smoking seemed to be somewhat questioned, as three weeks' persistent firing had not sufficed to get the chimney warmed sufficiently to keep it from smoking dreadfully every time the fire was kindled, or to prevent the gas from pouring out when the coal was put on. It was so glaringly incorrect that I had to abandon it and commence a search for some remedy that would leave a less unpleasant odor. The fire was allowed to burn out in the furnace, and a diligent search commenced for the cause of offence in these new flues. (I should have remarked that the man who put up this furnace had been sent for, and, after a thorough (?) examination, pronounced it "all right.") There was a stove in the third story, the pipe of which entered the furnace-flue. I commenced there by withdrawing the stove-pipe, and found a splendid draught. From there I went to the cellar, took down the furnace-flue, and found the smoke preferred going out to going in. My wife then commenced throwing pieces of coal in at the pipe-hole in the third story, while I listened in the second story and heard them rattling down with perfect freedom. Listening in the parlor, they were heard rattling along to a point just opposite the parlor mantel, where *I heard them stop*, as our friend from the Green Isle would say. More trouble ahead. I sank back in the chair in a fit of perfect dejection. As I sat there, with the drops of perspiration rolling off my face, endeavoring to calculate how many days it would take to get the mantel-man out from town to take the marble mantel down, and then get the bricklayers to cut open the flue to remove the obstruction, and get the mantel reset, and to get the plasterers to come and patch up the plastering; also, about how many months' income it would require to pay for it; and, upon the whole, whether we would not have to put up stoves and run the pipes out of the windows, or somewhere else; all at once a bright idea flashed across my mind—to have some burning coals thrown down from the pipe-hole in the third story. I waited and watched some little time and felt almost in despair, until at last down came a coal of fire, and then a strong woolly smell soon filled the cellar. Upon looking in at the pipe-hole I noticed large pieces of blanketing tumbling down. The whole mystery was now solved. The servant-girl, the preceding winter, had stopped up the pipe-hole with a piece of blanket, and it was found easier to push that into the flue than to pull it out when they put up the stove. I scarcely need add that the splendid draught was established as soon as the chimney became heated, to the great

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rejoicing and comfort of the family. There was no more trouble about "carbonic acid" or "carbonic oxide" through the solid iron.

Now I would just like to suggest to the French Academy of Sciences, who I understand are at present much exercised about the gas phenomena, the propriety of examining this blanket question, and give the hot-coal experiment a thorough trial. I can assure them from my own experience that the public would be utterly astonished at a correctly prepared statement, showing the large proportion of flues that are entirely choked up with blankets, mortar, soot, or their equivalents, and the almost universal inadequacy of modern flues to perform the service required of them. And until the public good shall be served by the timely smothering to death—which fortunately is rapidly occurring—of the present generation of wilfully ignorant architects and builders,* I would advise all persons purchasing new houses at once to tear the chimneys down to the foundation and put in the improved terra cotta flues—cheaper in the end than brick—before ever attempting to occupy them. We know this will be a very unpopular recommendation, and but few mechanics who have stoves or heaters to sell will risk selling their wares by giving any such advice, because their *neighbor* will say to the owner that "his house can be perfectly warmed and ventilated without going to any such expense, if he will only use *their* apparatus." Soothsayers and deceivers all of them. It is but one continued deception and disappointment. Such flues are like aching teeth; the sooner they are out the better. With a well-constructed flue, and consequent strong draught, with the combustion which can be and should be completely regulated by the admission of air under the fire, controlled by a perfectly air-tight damper, and *no damper in the smoke-pipe*—which it should be against the law to use—ninety-nine hundredths of all the practical difficulties about the escape of gas would be gotten rid of. And then, perhaps, the wisdom of the French Academy of Sciences will be able to suggest some remedy for the remaining portion, which no doubt may still persist in oozing through the iron castings.

* This was written two or three years since. There has been a great change in the opinions of these professions since that time.

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[From *The Manufacturer and Builder.*]

VENTILATION—COOLING.

It comes so natural to say ventilation and *warming*, that it is quite an effort to substitute *cooling;* it is quite a necessary substitution, however, for such weather as we have been passing through for the few months past. And why not pay some little attention to the additional comfort that might be gained three or four months in the year, by a little attention to artificial cooling, as well as to devote so much to the artificial heating for the six cooler months. One of the most easily reformed discomforts to which New Yorkers are so universally subjected is the heat and smells from the kitchen. In summer, when the kitchen is so much hotter than the rooms above, this disagreeable feature of our basement kitchen is especially noticeable. Our elegant houses soon become unendurable, particularly for our wives and daughters, who are obliged to flee to the mountains or to the sea-side, to escape this disagreeable par-boiling or premature roasting, which would have to be endured if the summer were spent in any of our fashionable city houses.

Why is it that men of intelligence, men of good ordinary common sense, will allow their architects and their builders to spend immense sums for the erection of a magnificent residence, and allow them to put the great fire directly under it, without a single crack for the escape of all the surplus heat and smells excepting by the main stairway? You can scarcely broil a steak or make a cup of coffee, without filling every room above it with the odor thereof; in fact, you might almost say the whole house is turned into one large cooking-pot. Now, it takes but a small amount of common sense, and fewer dollars than is commonly spent in a single visit to the fashionable watering-places, to remedy all this. A well-ventilated house on the high lands in the centre of New York City should be about as healthy, and could be made as comfortable a place to spend the whole year, summer included, as can be found in any civilized country on the face of the earth. But some very radical though perhaps quite simple modifications would be required in their construction.

One would be, to either ventilate the kitchens or put them in some other position in regard to the main building. In Philadelphia, the kitchen is universally placed in a back building extending beyond the main part of the house. This, however, is not generally

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applicable to the shape of lots and style of building in New York. There would be some decided advantages in putting the kitchen in the attic, though it might be quite inconvenient in other respects. At any rate, we should prefer to allow the credit of such a radical change in Bridget's headquarters to be given to some of the numerous bodies of energetic reformers rather than to attempt it during the little remnant of our natural life. It would be much more congenial to our taste, and in accordance with our experience, to disturb the general position and character of said headquarters just as little as possible. But instead of using the hall-way, and, in fact, the whole house, as the ventilator for the kitchen, we would let the kitchen have a ventilating shaft of its own; not simply a little rough flue, some four by eight inches probably, just enough to carry off the steam from one tea-kettle, but a shaft not less than three feet square—one that would be of some service. It may at first sight be thought a little difficult to get such a flue in an ordinary house directly from the kitchen out of the roof—but if it be *wanted*, and there is a determination to have it, there can be some way found of getting it with but little trouble.

For the purpose of illustrating this more fully, we have had engraved the plans of the basement and first story of a house now in process of completion on Fortieth street, near Fifth Avenue. By reference to these plans, for which we are indebted to L. W. Leeds, engineer in charge, it will be seen that there is a large ventilating shaft, A, $3 \times 3\frac{1}{2}$ ft. area, and about seventy-four feet high, passing directly through the roof. When possible, it is always best to get the grand shaft directly over the cooking-range, but it is frequently quite inconvenient to do so, and in such cases it is necessary to make the best arrangements possible in some other place.

In this case, it is a considerable distance away; but its efficiency is secured by carrying the smoke-pipe from the kitchen-range across the cellar, and into a well-constructed flue, which is eight inches by twenty-four, and perfectly straight for seventy feet in height, which will secure a splendid draught at all times. Two good results are obtained by thus carrying the smoke-pipe across the room. In the first place, we get rid of the heat from the smoke-flue, which generally adds several degrees of heat to the rooms through which it passes; and in the second place, the excess of heat escaping from the kitchen-fires secures a strong upward current

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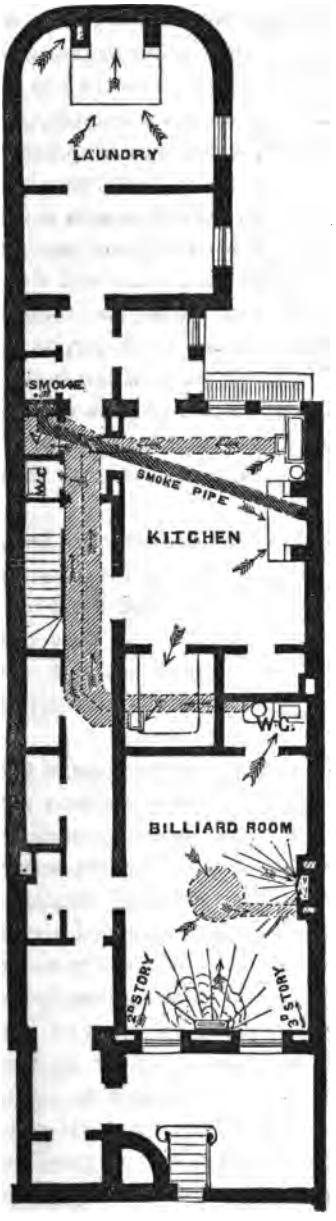
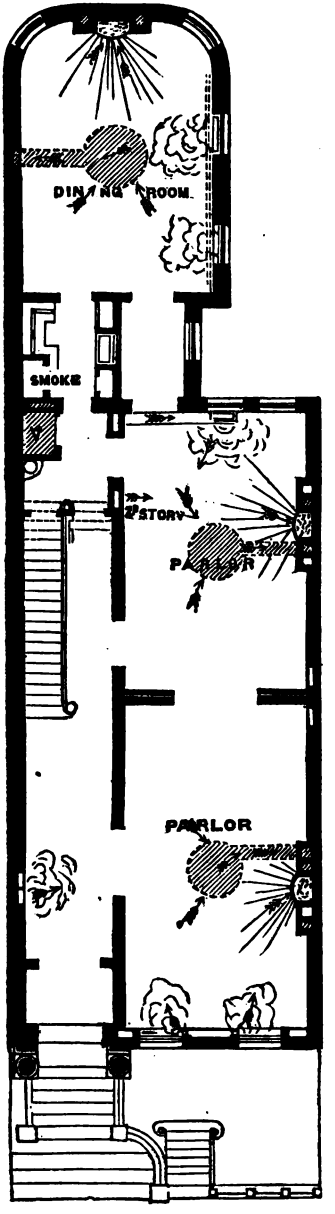


BASEMENT



FIRST STORY

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through the grand ventilating shaft. The space between two joists is used both at top and bottom of the kitchen for exhausting the air and excess of heat into that shaft, also a large register from the top of the hall-way adjoining the kitchen. Thus there will constantly be a large volume of air drawn from the kitchen, which will frequently be supplied by air coming in at the open doors and windows; but in winter, when these are mostly closed, the air will be drawn from the rooms above, which in their turn will be supplied by air passing through the warm-water apparatus; consequently the air will flow into the kitchen from the surrounding halls and rooms, and escape therefrom, instead of overflowing the kitchen by fresh air, as is usual, and allowing it to escape from them to all parts of the house. In the evenings, especially in summer, when the lower parts of the house are shut up, this shaft will draw off an immense amount of air, and the cooler air will flow in at the upper windows and thus leave the temperature of the whole house cool.

It is thus seen that a very little ingenuity will convert this heat, which is generally so annoying, into a valuable power for cooling the whole house—and then our well-furnished, well-ventilated city houses would be as much more comfortable and healthy than the ordinary rooms found at the crowded and temporary houses of our fashionable watering-places, as an open cottage in the country is more pleasant than our present fashionable city houses.

Of course, in winter an important part of the arrangement for ventilation is to have an abundant supply of partially warmed air flowing into all parts of the house. In the case under consideration, it is warmed by an apparatus that can be used for hot water in mild weather, or for low-pressure steam in very cold weather. Of course, great care is taken not to have too much warmed air in the house, as that is necessarily very debilitating; but every room is well provided with *direct radiation*, in some of the rooms from open fires, and in others by exposed pipes, heated by steam or hot water. Several pipes are also run along under the floor by the windows, for the purpose of keeping the floor warm and to counteract the cooling influence of the exposed windows. Special ventilators are placed over all the gas-burners, and wherever possible the warmed air is brought in at the coldest point of the room, which is of course under the external windows.

The foregoing cuts are copies of the original plans made before the building was erected, and the above article was written before

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the work was done. It is now interesting to know the practical working as executed.

In attempting to start fire in the kitchen range in the Autumn I noticed an unusual interest manifested by the mechanics about the building, and on inquiring I found a decided opinion of incredulity as to the success of the attempt to carry the smoke from the range in the kitchen down to the bottom of the cellar and across to the smoke pipe, as indicated on these plans.

I learned there had been previous attempts to light the fire, which had filled the whole house with smoke.

Care had been taken to explain to the proprietor that it would be necessary on starting a fresh fire when the flues were all cold to first build a fire at the bottom of the main shaft before lighting one in the range; but as he was not present this had been neglected, and of course the newly completed flues being damp and cold, not a particle of smoke or gas would go that way.

The heavy gases would accumulate in the flue below the range, and there remain.

The cook was in a grand state of excitement, declaring it was entirely against nature to attempt to make the smoke go down instead of up; she knew it would never work, and she could never do a thing with it.

As the family expected to move in the next day, the time seemed short to effect so radical a change in the education of that important personage; and from my many former attempts at such education, I deemed it quite prudent to acquiesce at once in the proposal to send for the range man to turn the smoke into the usual flue immediately over the range, and allow it to pass up through the library and main rooms of the building as usual.

But the delay of a few hours in the arrival of the range man gave me a good opportunity to build a fire at the bottom of the upright flue, and have a bright hot fire in the range on his arrival. The draught of that flue was then magnificent, and no doubt would have been quite sufficient as long as there was a fire in the range every day.

But it is not desirable to resort to the expedient of carrying a gas flue downwards if it can possibly be avoided.

An excellent draught may be secured in this way most unquestionably, but additional care is required in starting the fires when the flues are cold; and again, any opening into the flues below the

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level of the fire is liable to give much trouble from the leakage of gas.

By a little ingenuity the smoke flue might be carried across the kitchen ceiling, thus avoiding the foregoing objections, or by care a double flue might be made upwards through the whole house in the usual position.

Some additional care would be required in either of these cases, but the object to be gained, that of thoroughly ventilating the kitchen and the avoiding of the additional heat of the gas flue in the best rooms of the house, is so great that it would pay to go to a very considerable extra trouble to accomplish it.

The ventilation from the top of the kitchen into the large exhaust shaft is excellent, and the general ventilation and heating of the whole house is very good.

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EQUITABLE LIFE ASSURANCE SOCIETY.

We have prepared, and insert herewith, plans showing the arrangement for ventilating and warming the new building of the Equitable Life Assurance Association.

No class of men seem more keenly alive to the necessity for some radical modifications in our methods of ventilation and warming than our enterprising life assurance societies.

It is as important to them to know that those persons whose lives they have insured are not living in a foul, poisonous atmosphere, as it is for fire insurance companies to know that the buildings they insure are not filled with highly inflammable materials, or that the flues are not carelessly built and defective.

A well-ventilated house for their customers is a source of great profit to them.

The committee charged with the care of the erection of the building under consideration was exceedingly solicitous that no pains should be spared in providing the most perfect ventilation that could be devised. Many plans were submitted to them and urged with great persistence.

At one time they were quite favorably impressed with some of the schemes for forcing the air through the building by steam-driven fans, but after several months careful investigation they decided to adopt the heated shafts instead, and to heat to a considerable extent by direct radiation, and wherever possible to have the radiators placed under the external windows, with the fresh air supply introduced directly over each one. These plans were carried out. Owing to the great number of occupied stories, the fire-proof construction, &c., this building presented unusual difficulties to the introduction of any system of ventilation. Yet those difficulties were very satisfactorily overcome, which should be attributed in a great measure to the hearty co-operation of the architects, and the determination of the building committee to allow nothing to stand in the way of the thorough execution of the plans which they had decided upon.

It must be remembered that there are eight occupied stories; first, in the cellar there are three large boilers for heating and for power, two great engines for running the hoistways, and laundries, water-closets, safe deposit vaults, &c., &c.

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There are several kitchens, and in every story are many water closets, and all these in a fire-proof building, where no regard was paid to keeping the partitions one over the other. It may readily be imagined, therefore, that many singular contrivances had to be resorted to for the purpose of getting the flues for foul air across from one part of the building to another. In some cases the foul air is carried down two stories, and then horizontally 75 or 100 feet to an exhaust shaft, and in nearly every case with perfect success.

There are a few water-closets that were introduced after the building was quite finished, about which I was not consulted, and no adequate provision for their ventilation was provided. But these scarcely affect the general result.

The aggregate area of all the exhaust shafts is one hundred and seventy-two square feet, and by a careful measurement of the velocity of these by an anemometer, it was ascertained that the average was about six feet per second, which makes for these exhaust shafts alone a discharge of 61,000 cubic feet every minute, or 37,000,000 for a day of ten hours. This constant stream of impure air is flowing from the building at all times, but so quietly as to be almost unnoticed, and is really unknown by a large part of the occupants of the building; and the heat being so equally distributed on the exterior of the rooms that there was very little complaints of cold draught anywhere in the building, and I believe not one request during the whole of last winter to close up any of the regular ventilators, either top or bottom.

I felt quite solicitous about the ventilation in the large business hall, as it was so entirely surrounded by other rooms and had no external windows; but the ventilation of that room is so perfect that at no time, summer or winter, windy or still, can you perceive any of that peculiar odor of crowded rooms.

There is at times a perceptible odor drawn in from the dining-room, and kitchen adjoining, which was annexed after the building was nearly completed. and without the proper attention given to its ventilation, and which has not yet been remedied.

NOTE.—Since the above was written, I was quite surprised to see some considerable modification in the heating arrangements in rooms that gave the best results the two previous winters. I have not been able to learn the reasons for such changes, but it is probably to accommodate the peculiar individual preferences of some of the parties concerned.

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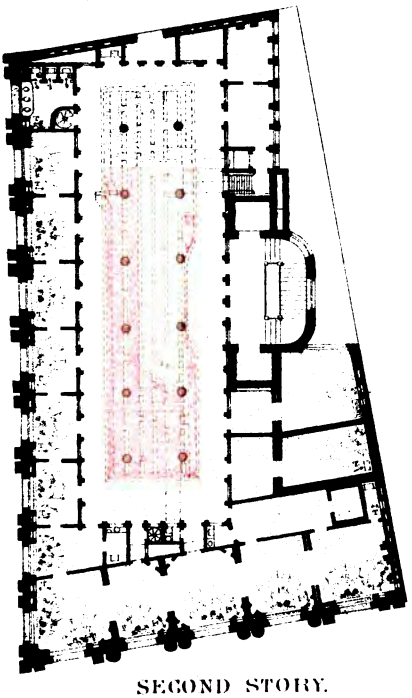
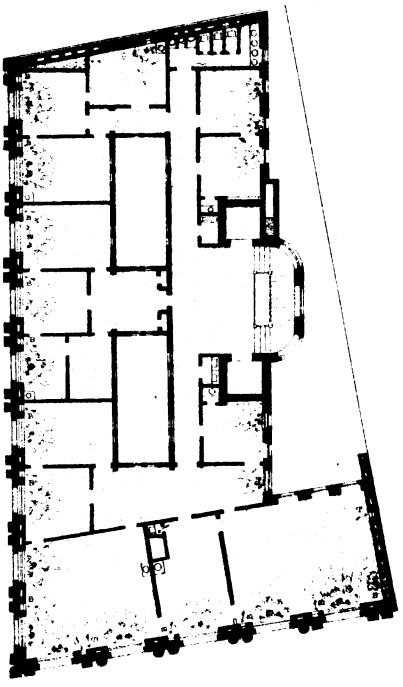


SECOND STORY.



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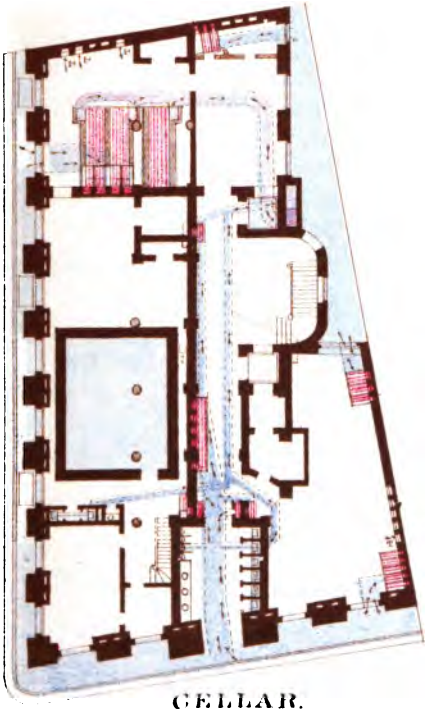

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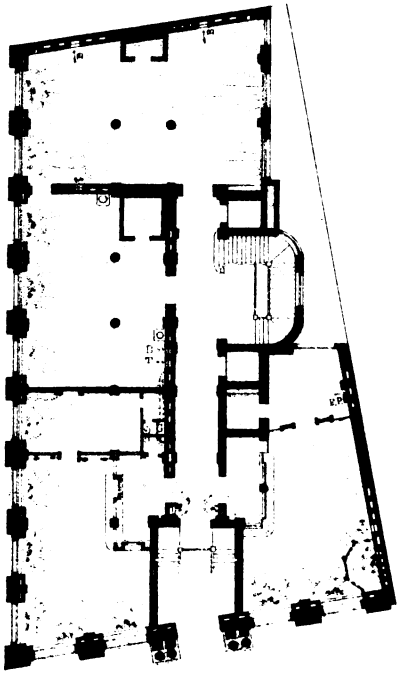

FIRST STORY.

New Building of Equitable Life Insurance Company.

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NEW YORK, 110 TRINITY BUILDING, *July* 18, 1871.

The ventilation of a large and complicated structure is apt to present such difficulties of arrangement as in many cases seriously to interfere with the appearance and even with the structural details of the whole work. On this account, I have always been inclined to think it the most vexatious and unsatisfactory portion of the duties which the architect is called upon to perform. But the result of Mr. Leeds' work as engineer of the ventilation and warming of the Equitable Life Assurance Company's building has been such as quite to overcome my former prejudice against ventilating engineers in general.

The skill and tact displayed by him in arranging the ventilating shafts and the various flues connecting therewith, in many cases for rooms at a considerable distance from such shafts, are certainly very creditable to him, and quite beyond any expectations which I had been able to form of their probable results.

With the liberal distribution throughout so large a building of the sources of contamination inseparable from its free and daily use, the entire absence of any unpleasant odors throughout has become, to my mind—not in the outset, I must acknowledge, very sanguine as to the probable results—the best and most satisfactory indication of an almost complete success.

ARTHUR GILMAN, *Architect.*

NEW YORK, *July* 15, 1871.

Mr. Leeds' services as engineer of ventilation and warming in the construction of the Equitable Building were performed quite to my satisfaction. Much ingenuity was required to devise methods for securing good ventilation to most of the rooms in so complicated a building; but very general success has been obtained, and that too without interfering with the various and exacting architectural arrangements.

EDWARD H. KENDALL, *Architect,*
120 Broadway, N. Y.

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Dwelling-House in the Country.

The accompanying plan represents the arrangement of the hot-air furnace, the heating flues, and ventilation for a gentleman's cottage near New York.

As he proposed to have open grate fires in the principal rooms, it was not thought necessary to go to the additional expense of introducing steam or hot water.

It will be noticed that all the registers for admitting warmed air are placed on the sides of the room farthest from the door opening into the hall and under the windows; the warmed air consequently has to flow across the whole room before escaping into the hall.

It is very common to place them near the hall-door, and when that is open the warmed air escapes directly up the stairway without warming the room perceptibly.

It is also proposed to lay the vestibule in tile, and allow a current of heated air to pass under it so as to heat it moderately.

This will give a pleasant warmth, and insure a good circulation to the whole hall and stairway. The whole house can almost be warmed by a heated floor in this way.

In the second story the heated air is discharged from the jamb on the side opposite the ventilating flue, so that it shall be obliged to make the circuit of the whole room before escaping.

The main ventilating shaft is back of the range, with the smoke-flue from the range running up in the centre of it.

This will give sufficient heat to insure a constant draught at all times, and forms one of the simplest and cheapest means of ventilating a dwelling-house that can be had.

The laundry, store-closets, water-closets, kitchen, etc., are all ventilated by this shaft.

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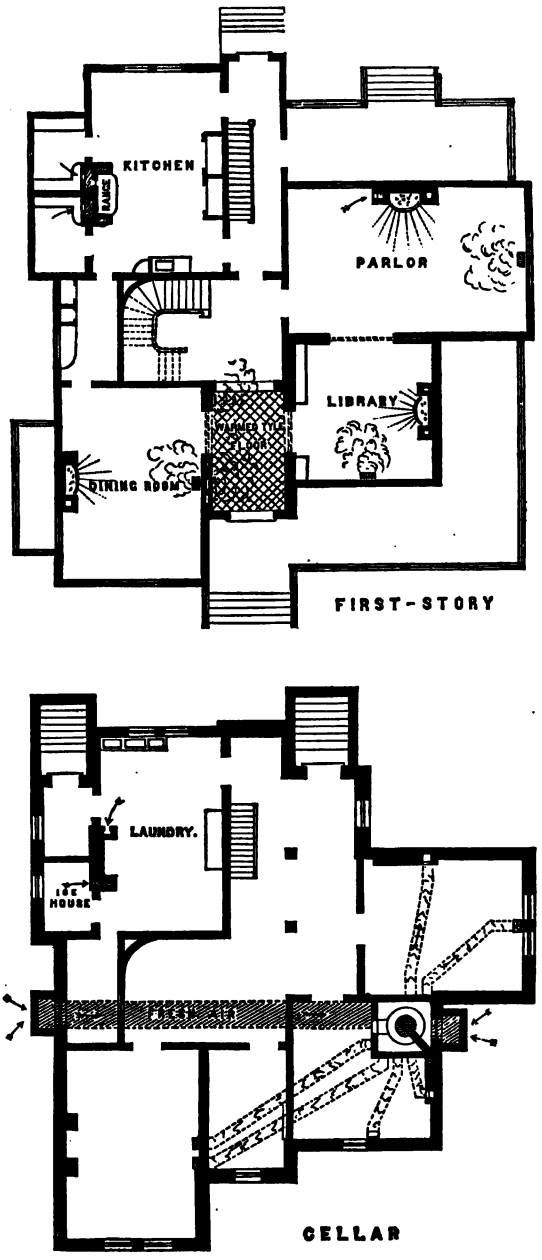

PLAN OF DWELLING IN THE COUNTRY.

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LIST OF BUILDINGS FOR WHICH PLANS HAVE BEEN GIVEN FOR VENTILATION AND WARMING.

THE following is a list of some of the principal buildings for which I have given the plans and specifications for the warming and ventilation, since the close of the war.

A large part of my business consists in giving these only, and in most cases I do not superintend the execution of the work, not unfrequently never hearing from them after being paid for.

Of course, in many cases the plans are so *improved* by the owner or architects as to be beyond recognition by their designer, and sometimes so *improved* as to be thought worthy of an application for a patent.

Those coming under my notice, which have been executed with a reasonable degree of accuracy, have very generally given much satisfaction.

CHURCHES.

	Architect.
St. Ann's Church, Brooklyn	Renwick & Sands.
St. John's Church, Clifton, S. I.	Arthur Gilman.
Church corner Fifth Avenue and Nineteenth Street	Not executed.
St. John's Church, Buffalo, N. Y.	Arthur Gilman.
Methodist Church, Middletown.	
Clinton Avenue D. R. Church, Newark	Thos. Roberts.
Church cor. Twentieth Street and Sixth Avenue, N. Y.	
St. John's, Chicago, Ill.	Cass, Chapman.
Baptist Church at Troy, N. Y.	
Wabash Av. Church, Chicago	Rose & Chapman.

COLLEGES AND SCHOOL-HOUSES.

	Architect.
Findlay Street Public School, Cincinnati	Board of Education.
Public School at Orange, N. J.	J. P. Huber.
Public School at Worcester, Mass.	Earle & Fuller.
High School at Hartford, Conn.	G. H. Gilbert.
Public School at Salem, Mass.	Martin & Thayer, not ex'd.
Farnham College, New Haven, Conn.	Russell, Sturgis, Jr. & Co.
Public School at Albany, N. Y.	Woollet & Ogden.
Theological Hall, New Haven	R. M. Hunt, not executed.
Stevens Institute, Hoboken, N. J.	R. Upjohn.

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PUBLIC BUILDINGS.

	Architect.
House of Representatives, Wash.	
Blind Asylum, Columbus	Wm. Tinsley.
St. Cloud Hotel, N. Y.	
Retreat for Insane, Hartford	Vaux, Withers & Co.
Hudson River Hospital for Insane	Vaux, Withers & Co.
Shepard Asylum, Baltimore	C. Vaux.
German Club House, Brooklyn	C. Pfeiffer.
Senate Chamber, Albany.	
County Court Room, Albany.	
City Hall, Pittsburgh, Pa	J. W. Kerr.
Club House at Boston	Ware & Van Brunt.
Union League Club House, N. Y.	
New Building Brooklyn Union	Not executed.
Treasury Department, Washington	A. B. Mullett.
Brooklyn Orphan Asylum	George Hathorne.
Chicago Tribune.	

DWELLING-HOUSES.

	Architect.
J. D. Cameron, Harrisburg, Pa	Vaux, Withers & Co.
Dr. Tracy	H. H. Holly.
Henry B. Hyde, N. Y	Gilman & Kendall.
Tenant House, Boston.	
W. S. Weed, Binghamton.	
B. Slessinger.	
Alfred Mills, Morristown	Harney.

BANKS AND INSURANCE.

	Architect.
Equitable Life Assurance Society	Gilman & Kendall.
Williamsburgh Savings Bank	Geo. B. Post.
N. W. Life Insurance Company, Milwaukee	Townsend Mix.
Merchants' Bank, 42 Wall Street, N. Y.	
Sears' Block, Boston, Mass	Cumming & Stars.
German Savings Bank, New York	H. Fernbach & E. H. Kendall.
Marine Insurance Company, New York.	
Metropolitan Bank, New York.	
American Exchange Bank, New York.	

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The subjoined are a few of the Letters received from prominent Sanitarians and others.

OFFICE OF THE SUPERINTENDENT OF HEALTH,
PROVIDENCE, August 5, 1867.

FRIEND LEEDS.

Your Lectures on Ventilation have been received. I am much interested in them, and think the views given are correct. I hope they will be widely circulated. Too much cannot be said to the people upon the subject.

Ventilation is all-important. Indeed, I think that if the air could be constantly kept in motion, the worst sources of impure air in our cities would be rendered almost free from danger.

In seasons of epidemic cholera, the most oppressive feature of danger is the stagnation which exists in the atmosphere. There was good sense and true philosophy in the old custom of burning bonfires to keep off disease. I must close, wishing you much success in your efforts to awaken the people to the importance of this subject.

Truly yours,

EDWIN M. SNOW, M. D.,
Superintendent of Health.

BANGOR, MAINE, August 23, 1867.

MY DEAR LEEDS.

Your pamphlet was duly received. I have read it with much interest, and believe it to be worthy of extended circulation. It is the clearest paper on the subject I have yet read.

Yours, in haste, A. C. HAMLIN, M. D.

---

64 Madison Avenue, NEW YORK, Aug. 23, 1867.

MY DEAR FRIEND.

I have just read your Lectures on "Ventilation," and I am very much obliged to you for the entertainment and instruction they have given me. You have very happily hit upon a style which is neither flippant nor dry. I am sure the lectures will be read, and if read, they will do a great deal of good.

I have all my life been talking and writing in this direction, imploring the people to take less medicine and more pure air; and I feel truly grateful for the help your strong shoulders have given me in what has thus far proved to be a labor of Hercules.

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Your particular method of ventilating buildings I had many opportunities of proving while I was Medical Inspector U. S. A., and I assure you that no plan was ever more simple and inexpensive—none could have been more effective. Indeed, I may say that I never knew it to fail.

To you, therefore, I fully believe the country is indebted for the lives of many thousands of men.

With sentiments of esteem,

I remain yours truly,

FRANK H. HAMILTON, M. D.,

Prof. Principles of Surgery, Military Surgery, Hygiene, &c.,

Bellevue Hospital Medical College, N. Y.

Author of Work on Fractures and Dislocations, Treatise on Military Surgery, &c.

L. W. Leeds, Esq.

Office of the Metropolitan Board of Health,

No. 301 Mott Street,

New York, August 26th, 1867.

Friend Leeds.

Your Lectures on Ventilation have given me much pleasure, and have renewed my confidence in the utility of popular instruction upon the subject. I heartily thank you for the thoughtful care with which you have set forth all the essential principles of ventilation, in language so free from technical words, and so full of plain and homely illustration, that even an uneducated reader can fully understand all you have written. The good Dr. D. Boswell Reid, Dr. Wyman and myself had each attempted to use such a style of explanation and instruction; but you have far excelled us all.

The first want of every living being is fresh air, and unless the human lungs are supplied with such air constantly at the rate of from ten to thirty cubic feet every minute, by night as well as by day, perfect health and vigor cannot be preserved. Then, too, there are exhaled from the surface of the body and from the lungs, such quantities of waste organic matter, which tend to immediate putridity, that it, together with the carbonic acid, would keep the human body immersed in a deadly vapor of these exhalations, were not fresh air supplied. The illustrations by which you have made these truths easily understood, are admirably given in your lectures, and the method, by which you would best insure success in removing the foul and supplying the pure fresh air in every place where persons live or sleep, are, as I believe, from my own careful studies of this subject, most correct and trustworthy. Indeed, I am able to say that, in my examinations of the vast number of hospitals and buildings which you ventilated during the late war, under authority from the intelligent and humane Quartermaster-General of the army, the proof of entire success in your work was everywhere witnessed. Simplicity, invariable certainty and a liberal sufficiency characterizes these admirable methods of yours.

I wish every family in the land had a copy of these lectures.

Sincerely yours,

ELISHA HARRIS, M. D.,

Corresponding Secretary Metropolitan Board of Health.

To Lewis W. Leeds, Esq.

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VAUX, WITHERS & Co., Architects,
No. 110 Broadway, NEW YORK, August 27th, 1867.

DEAR MR. LEEDS.

I am glad to receive your Lectures in printed form, and trust that they may be widely read throughout the community.

Having been in the habit for several years past, of consulting with you professionally in regard to the arrangements to be made for heating and ventilation in plans for public and private buildings, I take this opportunity to acknowledge the value of the aid thus given; and as I feel assured, from a lengthened persona experience, that your thorough knowledge of the subject, both theoretically and practically, is calculated to render your assistance particularly valuable in the adjustment of complex and intricate plans, I trust that one result of the circulation of your interesting pamphlet may be to introduce you more widely to members of the architectural profession.

I remain, Dear Mr. Leeds,
Yours faithfully,
CALVERT VAUX.

LEWIS W. LEEDS,
Heating and Ventilating Engineer.

---

110 Broadway, NEW YORK, Aug. 30th, 1867.

Mr. LEWIS W. LEEDS was employed early in the war of the rebellion by the Sanitary Commission, as an agent to urge the necessity to the health and strength of the army, of the thorough ventilation of tents and quarters, and to devise and suggest to the proper officers the adoption of the best means for this purpose.

At a later period of the war, at the suggestion of the Commission, the Quartermaster's Department engaged his services, and gave him large discretionary powers for the ventilation of hospitals. He was thus employed during all of the war, with great advantage, and the improvements which he brought about were unquestionably the means of saving thousands of lives. * * * *

Mr. Leeds has a special talent for making improvements in houses of ordinary construction, by means which may be readily adopted, and with materials which may be anywhere procured without difficulty or great expense.

Mr. Leeds' course of lectures on Ventilation is calculated to supply instructions of great practical utility. An invaluable addition to the health, happiness and wealth of the nation would result, if they could be delivered before every school in the country.

FRED. LAW OLMSTED,
First General Secretary of the Sanitary Commission

TREASURY DEPARTMENT,
Office of the Supervising Architect, Sept. 11th 1867.

MY DEAR FRIEND.

Your valuable Lectures on Ventilation have been received, and have been read with much pleasure, more especially as you are about the only person I have ever met, who, after making the ventilation and heating of buildings a specialty, has condescended to follow the laws of nature, and provide the means of adapting

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them to our artificial modes of life. Your lectures show a thorough study and knowledge of the principles involved, which are, like all natural principles, very simple if once understood. I have also to take this means of acknowledging the valuable aid that I have received from you on many occasions, and to express a hope that you will not despair, but relying on the adage that "truth is mighty" &c., go on with your exposures of the absurdities of the complicated and costly humbugs that are so fashionable at present, and trust you will succeed not only in your missionary labors, but find them pecuniarily profitable.

Very respectfully,

A. B. MULLETT,
Supervising Architect.

LEWIS W. LEEDS, Esq.,
Engineer Ventilation and Heating,
Germantown, Penn'a.

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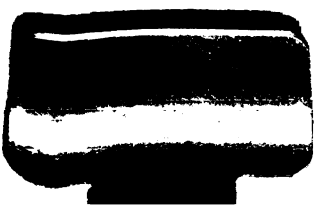

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